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**SKYLAB EXPERIMENT PERFORMANCE
EVALUATION MANUAL**

**Appendix J: Experiment M555
Gallium Arsenide Single Crystal
Growth (MSFC)**

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16. ABSTRACT This appendix contains a series of analyses for Experiment M555, Gallium Arsenide Single Crystal Growth (MSFC), to be used for evaluating the performance of the Skylab corollary experiments under preflight, inflight, and post-flight conditions. Experiment contingency plan workaround procedure and malfunction analyses are presented in order to assist in making the experiment operationally successful.			
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**APPENDIX J. EXPERIMENT M-555, GALLIUM ARSENIDE
SINGLE CRYSTAL GROWTH (MSFC)**

Prepared By:

M. S. Byers

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DEFINITION OF SYMBOLS

AM	Airlock Module
cb	Circuit breaker
CCU	Crewman Communications Umbilical
CM	Command Module
CRT	Cathode ray tube
ERD	Experiment Requirements Document
FBD	Functional Block Diagram
FO	Functional Objective
GMT	Greenwich Mean Time
HOSC	Huntsville Operations Support Center
IVA	Intravehicular Activity
It	Light
MDA	Multiple Docking Adapter
MRD	Mission Requirements Document
MSFC	Marshall Space Flight Center
MSC	Manned Spacecraft Center
N/A	Not Applicable
NC	Normally Closed
OMSF	Office of Manned Space Flight
P_{f_t}	Total probability of failure
P_s	Probability of success

DEFINITION OF SYMBOLS (Concluded)

PI	Principal Investigator
SL	Skylab
sw	Switch
SIA	Speaker Intercom Assembly
TBS	To Be Supplied
vlv	Valve

SECTION I.

EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL
GROWTH PRE-FLIGHT OPERATIONS
EVALUATION ANALYSIS

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 1 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number*	Remarks
	min	nom	max		
3 0 Analyze and predict Skylab Experiment M-555, Gallium Arsenide Single Crystal Growth facet performance profile.				N/A	Refer to functional item 3 1.
3 1 Make explicit statements about objectives in qualitative and quantitative terms				N/A	Refer to functional item 3 1.1
3 1.1 Specify duration that the experi- ment is required to operate and provide useful information		115 hr		N/A	The experiment requires approximately 115 hr for growing the single crystals. The experiment operator is required to monitor and record temperatures of the crystal growth package every 30 min during the first 3 hr of the heating cycle, every 12 hr during the remaining 112 hr of the heating cycle, and every 30 min for the first 3 hr of the 9-hr cooldown time. Approximately 120 min is the total crew time required for experiment preparation, temperature monitoring, and experiment termination.
3 1 2 Specify the types of criteria that are to be maximized or minimized.				N/A	References 1 and 2 The objective of Experiment M-555 is ● Functional Objective (FO)-1 --Perform growth of single crystals and collect data and samples for return to earth
*Criticality Category Number Definition <ul style="list-style-type: none"> ● Category I--Experiment and equipment whose failure could adversely affect crew safety. ● Category II--Experiment and equipment whose failure could result in not achieving a primary mission objective, but does not adversely affect crew safety ● Category IIIa--Experiment and equipment whose failure could result in not achieving a secondary mission objective, but which does not adversely affect crew safety or preclude the achievement of any primary mission objective. ● Category IIIb--Experiment and equipment whose failure could not result in a loss of primary or secondary mission objectives and does not adversely affect crew safety. 					

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 2 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.1.2 (Concluded)					The basic objective of Experiment M-555 is to take advantage of the absence of gravity to grow crystals of gallium arsenide from solution and produce material of high chemical and crystalline perfection.
3.1.3 Specify the percentage of acceptable max /min. for each criterion.			100 %	N/A	References 2 and 3. Since Reference 2 specifies only one FO for Experiment M-555, accomplishment of the FO would signify accomplishment of 100 % of the experiment. It is not considered feasible nor desirable to assign relative weights to accomplishment of portions of the FO. Reference 2.
3.1.4 Specify experiment constraints. <ul style="list-style-type: none"> • Musts • Must Nots • Wants • Don't Wants. 				N/A	<ul style="list-style-type: none"> • Musts <ul style="list-style-type: none"> -- Experiment M-555 must be performed on SL-1/SL-2 because it is necessary to retain the samples (before experiment operation) in the molten state, and provisions have been integrated only in the SL-2 Command Module (CM) and the Multiple Docking Adapter (MDA) to support this requirement. --One vacuum chamber cycle is required for performance of Experiment M-555. --Post-flight telemetry data of Thruster Attitude Control Subsystem firings and accelerations are required. --Voice recordings of astronaut comments during experiment performance are required. Crewman observations during experiment performance must be entered in the appropriate section of the MDA Data File --Experiment M-555 must be performed after Experiments M-551, M-552, and M-553 since these experiments require the use of the M-512 facility battery, which has a limited lifetime. --The M-512 vacuum work chamber must be evacuated (less than 10^{-4} torr) for Experiment M-555 operation. • Must Nots <ul style="list-style-type: none"> --N/A.

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 3 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.1 4 (Concluded)					<ul style="list-style-type: none"> • Wants --Spacecraft accelerations are to be avoided if possible.
3.1.5 Specify experiment operational tolerances				N/A	<ul style="list-style-type: none"> • Don't Wants --N/A. <p>References 1 and 2.</p> <ul style="list-style-type: none"> • Musts --Approximately 1440 W-hr of energy at 28 ± 2 Vdc is required for the experiment sample heaters prior to experiment operation. This quantity is based on experiment performance in the MDA 20 days after launch (average 3 W x 480 hr). --Approximately 11,270 W-hr of energy at 28 ± 2 Vdc is required for growing the single crystals (average 98 W x 115 hr). --The experiment ampoules must be kept above 85 °F until experiment performance to prevent solidification of the liquid gallium.
<ul style="list-style-type: none"> • Musts • Must Nots • Wants • Don't Wants. 					<ul style="list-style-type: none"> • Must Nots --N/A.
3.2 Define decision rules and success criteria for the experiment objectives.				N/A	<ul style="list-style-type: none"> • Wants --N/A.
3.3 Specify experiment priority (numerical statement) for a given Skylab flight designation.				N/A	<ul style="list-style-type: none"> • Don't Wants --N/A. <p>References 1, 2, and 4.</p> <p>If the experiment is aborted, then the probability of success (P_s) is equal to 0.0. If the experiment is compromised and minimum information is salvaged, $P_s = 0.1 \rightarrow 0.5$, if maximum information is salvaged, $P_s = 0.5 \rightarrow 0.9$, if the experiment is completed as scheduled, $P_s = 1.0$.</p> <p>Experiment M-555 is scheduled for SL-1/SL-2, and is assigned a Flight Scheduling Precedence Number of 200.</p> <p>References 5 and 6.</p>

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 4 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.4 Briefly describe and list the major subsystems for Experiment M-555.				N/A	Refer to functional items 3 4.1 and 3 4 2
3.4.1 Describe the major functions.				N/A	<p>An effort will be made in Experiment M-555 to grow unique single crystals of gallium arsenide. Three samples are packaged in a single furnace heating package. During performance of the experiment the furnace will heat and cool the samples in a controlled manner to form single crystals of the sample material. The experiment package (furnace) is installed in the heat sink of the M-512 facility work chamber, and the work chamber is evacuated for performance of the experiment. Power for the crystal growth heaters is supplied by the CM during launch, and by Airlock Module (AM) Bus 1 through the M-512 facility both prior to and during experiment performance. Experiment data are provided by astronaut voice recordings, written observations in the MDA Data File, and by return of the crystal samples to earth for analysis.</p> <p>Reference 1</p>
3.4.2 List the major components				N/A	<p>Major components for Experiment M-555 are:</p> <ul style="list-style-type: none"> • Single Crystal Growth Experiment Container • Heating Blanket (part of experiment container) • Single Crystal Growth Package • Sample Ampoules (3) (part of crystal growth package) • M-554/M-555 POWER CABLE. <p>Performance of Experiment M-555 also requires the following items provided by the M-512 Materials Processing Facility:</p> <ul style="list-style-type: none"> • Vacuum Work Chamber • Control Panel • M554/M555 CRYSTAL GROWTH/COMPOSITE CASTING CLAMP <p>A Functional Block Diagram (FBD) is submitted as Figure J-1, and is used as a subsystem component listing for Experiment M-555. Critical subsystem components</p>

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 5 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3 4.2 (Concluded)					will be identified and evaluated for failure, and correlated to possible interface problems among the experiment, M-512 facility, carrier, and crew.
3.5 Specify the major subsystem interfaces between Experiment M-555 and the M-512 facility, the carrier, and the crew				N/A	References 1 and 3. An Interface Block Diagram is submitted as Figure J-2, and is used to define the interfaces for M-555.
<ul style="list-style-type: none"> • Physical <ul style="list-style-type: none"> --Mechanical --Electrical --Communications and Data --Support • Environmental <ul style="list-style-type: none"> --Natural and Induced --Contamination • Operational <ul style="list-style-type: none"> --Pointing and Control --Crew Safety --Sequence --Operability 					
3.5 1 M-555 Single Crystal Growth Experiment Container.				N/A	Refer to functional items 3 5 1 1 and 3 5. 1. 2.
3.5 1 1 Specify the total probability of failure (P_{f_1}) of the heater blanket		0.02		IIIa	The heater blanket is used to ensure that the temperature of the crystal growth package never drops below 85 °F. At this temperature, the liquid gallium in the package ampoules could freeze, degrading the experiment data, and possibly rupturing the sample ampoules. The blanket is constructed of 33 gage nichrome wire (inside heat-reactive tubing) sealed between two sheets of rubber. The blanket receives power from AM Bus 1 through CRYSTAL GROWTH HEATING PAD AM BUS 1 circuit breaker

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 6 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.5.1.1 (Continued)					<p>CB5 and the M555 SINGLE CRYSTAL GROWTH POWER CABLE. The electrical power is converted to heat in the nichrome wires and is transferred to the package by conduction and radiation. The blanket dissipates 6.5 W max. A strip of Velcro is stitched to each end of the blanket for securing the blanket around the crystal growth package. The following warning is printed on one of the Velcro strips: CAUTION - EQUIP MAY EXCEED 105 °F.</p> <p>If the nichrome heater wire were to break, the following would occur:</p> <ul style="list-style-type: none"> • Electrical <ul style="list-style-type: none"> --Power could not be supplied to the crystal growth package heaters since the blanket circuit is integral with the package heater circuit. • Support <ul style="list-style-type: none"> --Lack of power could permit the gallium solution to freeze and rupture the sample ampoules. This would cause experiment termination. • Communications and Data <ul style="list-style-type: none"> --If the gallium solution were to freeze and the ampoules remained intact so that the experiment could be performed, the experiment data would be degraded. <p>If the blanket heater wire were to short, the following could occur</p> <ul style="list-style-type: none"> • Electrical <ul style="list-style-type: none"> --CRYSTAL GROWTH HEATING PAD AM BUS 1 circuit breaker CB5 could open, preventing power from being applied to the experiment container and crystal growth package for maintaining the gallium solution in a liquid state. If the circuit breaker did not open, power dissipation in the package heaters would increase because of the reduced total resistance (package heaters and heater blanket heaters) so that the package temperature would be maintained or increased slightly <p>Indications of failure of the heater blanket are by astronaut observation of the following:</p> <ul style="list-style-type: none"> • Heater wire broken <ul style="list-style-type: none"> --The heater blanket and crystal growth package are relatively cool to the touch.

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 7 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.5.1.1 (Concluded)					<ul style="list-style-type: none"> Heater wire shorted --CRYSTAL GROWTH HEATING PAD AM BUS 1 circuit breaker CB5 opens.
3.5.1.2 Heater Control Circuitry.				N/A	Reference 7. Refer to functional items 3.5.1.2.1 through 3.5.1.2.7.
3.5.1.2.1 Specify the P_{ft} of the LAMP TEST switch S28.		0.04			The LAMP TEST switch S28 is located on the M-555 Single Crystal Growth Experiment Container, and is used to test the crystal growth package temperature history. The switch has three positions: LAMP TEST, OFF, and LO TEMP TEST. The switch is placed in the LAMP TEST position to verify LO TEMP light L10 is functional. If at any time the temperature of the crystal growth package has dropped below 85 °F, LO TEMP light L10 will illuminate when switch S28 is moved to LO TEMP TEST. The switch receives power from AM Bus 1 through CRYSTAL GROWTH HEATING PAD AM BUS 1 circuit breaker CB5.
				IIIb	If the switch were to fail in the OFF position, the following would occur: <ul style="list-style-type: none"> Communications and Data --An erroneous impression would be given of the status of LO TEMP light L10 or of the package temperature history. The experiment operator could be led to believe that the light bulbs were defective. A loss of data (i.e., the package temperature history) would occur.
				IIIb	If the switch were to fail in the LAMP TEST position, the following would occur <ul style="list-style-type: none"> Communications and Data --LO TEMP light L10 would glow continuously in this failure mode. A loss of data would occur (i.e., the package temperature history).
				IIIb	If the switch failed in the LOW TEMP TEST position, the following would occur: <ul style="list-style-type: none"> Communications and Data --This failure would also cause ambiguity concerning the temperature history of the crystal growth package. Unless the temperature of the package dropped below 85 °F, LO TEMP light L10 would never come on, and, when it did come on, it would remain illuminated as long as the experiment container received power

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 8 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.5 1.2.1 (Concluded)			-		<p>Indications of failure of LAMP TEST switch S28 are by astronaut observation of the following</p> <ul style="list-style-type: none"> • Failed OFF <ul style="list-style-type: none"> --LO TEMP light L10 does not illuminate when LAMP TEST switch S28 is moved to LAMP TEST. • Failed in LAMP TEST <ul style="list-style-type: none"> --LO TEMP light L10 illuminates when the experiment container is powered up. • Failed in LO TEMP TEST <ul style="list-style-type: none"> --No indication unless the crystal growth package temperature falls below 85 °F LO TEMP light L10 could then be observed illuminated while LAMP TEST switch S28 was in the OFF position. <p>Reference 8</p>
3.5.1.2.2 Specify the Pf_t of Thermostat S29.		0.04			<p>This normally closed (NC) thermostat opens if the temperature of the interior of the M-555 Single Crystal Growth Experiment Container rises to a level that could endanger the crewman. When the thermostat opens, power is removed from the crystal growth package and heater blanket heaters. Thermostat S29 is in series with NC Thermostat S30 and serves as a backup to S30 in case S30 fails closed. The operating range of Thermostat S29 is 95 °F (closes) to 110 °F (opens) ± 5 °F.</p> <p>IIIb Failure of Thermostat S29 closed would have no effect on the experiment since redundancy is provided by Thermostat S30.</p> <p>IIIb Failure of Thermostat S29 open would have the following effect:</p> <ul style="list-style-type: none"> • Communications and Data <ul style="list-style-type: none"> --The crystal growth package and container heater blanket heaters would be deprived of power, and this could allow the package temperature to drop to 85 °F. At 85 °F (± 5 °F) the package low temperature thermostat would close, activating relay K17A, which would close contacts K17 1/3, to provide a current path through Thermostat S37 to the package and heater blanket heaters. It is unlikely that the short amount of time that the package would be at 85 °F would allow the gallium solution to freeze.

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 9 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.5.1 2.2 (Concluded)					<p>The crewman would receive a low temperature indication, however, when he switched LAMP TEST switch S28 to LO TEMP TEST.</p> <p>Indication of failure of Thermostat S29 is by astronaut observation of the following</p> <ul style="list-style-type: none"> Failed closed <ul style="list-style-type: none"> --No indication Failed open <ul style="list-style-type: none"> --LO TEMP light L10 illuminates when LAMP TEST switch S28 is moved to LO TEMP TEST. <p>References 8 and 9</p>
3.5.1 2.3 Specify the P_{ft} of Thermostat S30.		0.04			<p>NC Thermostat S30 opens if the skin temperature of the M-555 Single Crystal Growth Experiment Container reaches touch temperature. When S30 opens, resistor R62 is placed in series with the package heaters and reduces power to the heaters. Thermostat S30 is in series with Thermostat S29 and serves as a backup in case S29 fails closed. The operating range of Thermostat S30 is 95 °F (closes) to 110 °F (opens) ± 5 °F.</p> <p>IIIb Failure of Thermostat S30 closed would have no effect on the experiment since redundancy is provided by Thermostat S29.</p> <p>IIIb Failure of Thermostat S30 open would have the following effect</p> <ul style="list-style-type: none"> Communications and Data <ul style="list-style-type: none"> --Resistor R62 (720 Ω, 10 W) would reduce the power available to the package and heater blanket heaters. Unless this allowed the package temperature to fall to 85 °F there would be no effect on the experiment. If the package temperature did reach 85 °F, the effect on the experiment would be the same as failure of Thermostat S29 open (refer to functional item 3 5 1.2.2) <p>Indication of failure of Thermostat S30 is by astronaut observation of the following</p> <ul style="list-style-type: none"> Failed closed <ul style="list-style-type: none"> --No indication

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 10 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.5.1 2.3 (Concluded)					<ul style="list-style-type: none"> Failed open --Crystal growth package temperature abnormally low. --LO TEMP light L10 may illuminate when LAMP TEST switch S28 is moved to LO TEMP TEST <p>References 8 and 9.</p>
3.5.1 2.4 Specify the P_{ft} of Thermostat S37.		0.04		IIIb	<p>NC Thermostat S37 provides a backup power path to the experiment package and heater blanket heaters if either Thermostats S29 or S30 failed open. If this happened, power would be interrupted to the crystal growth heaters and the package would eventually cool to the point that the package low temperature thermostat would close to activate Relay K17A and close contacts K17 1/3. Power then could flow through Thermostat S37 to the package heaters. The operating range of Thermostat S37 is 95 °F (closes) to 110 °F (opens) ± 5 °F</p> <p>Thermostat S37 is required to function only after another failure in the circuitry, therefore, failure of S37 will not be considered</p> <p>References 8 and 9.</p>
3.5.1 2.5 Specify the P_{ft} of LO TEMP light L10.		0.03		IIIb	<p>LO TEMP light L10 consists of two bulbs wired in parallel. The light is illuminated when the LAMP TEST switch S28 is switched to LAMP TEST, or when switch S28 is placed in LO TEMP TEST and the crystal growth package temperature has at any time dropped below 85 °F. The light lens is amber.</p>
				IIIb	<p>If one of the bulbs were to burn out, it would not affect the operation of LO TEMP light L10, since the other bulb would operate.</p>
				IIIb	<p>If one of the bulbs in LO TEMP light L10 should fail shorted, the following could occur:</p> <ul style="list-style-type: none"> Communications and Data <ul style="list-style-type: none"> --Neither of the two bulbs would illuminate since they are in parallel. The temperature history of the crystal growth package would be lost. Electrical <ul style="list-style-type: none"> --CRYSTAL GROWTH HEATING PAD AM BUS 1 circuit breaker CB5 may open when LAMP TEST switch S28 is placed in LAMP TEST and/or LO TEMP TEST. The crewman could reset the circuit breaker and continue

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT-OPERATIONS EVALUATION ANALYSIS (Sheet 11 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3 5 1 2.5 (Concluded)					<p>pre-experiment operation heating of the crystal growth package, or if he were ready to install the crystal growth package in the work chamber, he could leave the circuit breaker open and continue experiment preparation</p> <p>Indication of failure of LO TEMP light L10 is by astronaut observation of the following:</p> <ul style="list-style-type: none"> • Burnout <ul style="list-style-type: none"> --Burnout of one bulb would decrease the amount of illumination of the light face, but the crewman may not notice the difference. • Failed shorted <ul style="list-style-type: none"> --LO TEMP light L10 does not illuminate when LAMP TEST switch S28 is placed in LAMP TEST. --CRYSTAL GROWTH HEATING PAD AM BUS 1 circuit breaker CB5 may open when LAMP TEST switch S28 is placed in LAMP TEST. --If the crystal growth package temperature has at some time reached 85 °F, CRYSTAL GROWTH HEATING PAD AM BUS 1 circuit breaker CB5 may open when LAMP TEST switch S28 is placed in LO TEMP TEST. <p>References 3, 8, and 9.</p>
3.5 1 2.6 Specify the P_{ft} of relay K17A.		0.05			<p>Relay K17A is energized when the low-temperature thermostat in the crystal growth package closes. This occurs only if the temperature of the crystal growth package decreases below 85 °F. When relay K17A is energized, it opens contacts K17 1/2 to isolate the relay from the low-temperature thermostat, and closes contacts K17 1/3 to provide a power path to the LO TEMP TEST position of LAMP TEST switch S28 and to the package and heater blanket heaters through Thermostat S37. The two contact sets are magnetically latched in the activated position to maintain the crystal growth package under-temperature indication permanently. (Relay K17B resets the contacts, but it is activated during ground testing only)</p> <p>Relay K17A is required to function in two cases: 1) in the event of another failure that interrupts power to the crystal growth package, and 2) if the package is left unpowered long enough that the package cools to 85 °F. Failure of relay K17A in the first case would involve a double failure, therefore, the first case will not be considered.</p>

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 12 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.5.1 2.6 (Concluded)				IIIb	<p>Failure of relay K17A open(in the second case) would cause the following effect:</p> <ul style="list-style-type: none"> • Communications and Data <ul style="list-style-type: none"> --A loss of data for the crewman/operator would occur (i. e. , the temperature history of the crystal growth package).
				IIIa	<p>Failure of relay K17A shorted (in the second case) would have the following effect</p> <ul style="list-style-type: none"> • Electrical <ul style="list-style-type: none"> --CRYSTAL GROWTH HEATING PAD AM BUS 1 circuit breaker CB5 may trip when power is applied to the experiment container. • Communications and Data <ul style="list-style-type: none"> --Since power could not be applied to the crystal growth package and heater blanket heaters, the gallium solution could freeze and degrade crystal growth or rupture the ampoules and cause experiment termination. <p>Indication of failure of relay K17A is by astronaut observation of the following</p> <ul style="list-style-type: none"> • Failed open <ul style="list-style-type: none"> --LO TEMP light L10 illuminates when tested with LAMP TEST switch S28 in the LAMP TEST position, but does not illuminate when switch S28 is in the LO TEMP TEST position, the crystal growth package is relatively cool to the touch. • Failed shorted <ul style="list-style-type: none"> --CRYSTAL GROWTH HEATING PAD AM BUS 1 circuit breaker CB5 may trip when power is applied to the experiment container. --(If CB5 does not trip) LO TEMP light L10 does not illuminate when LAMP TEST switch S28 is placed in LAMP TEST and LO TEMP TEST, the crystal growth package is relatively cool to the touch. <p>References 8 and 9.</p>

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 13 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.5.2 M-555 Single Crystal Growth Package.				N/A	Refer to functional items 3 5.2.3 and 3.5.2.4.
3.5.2.3 Specify the P_{ft} of the M-555 Single Crystal Growth Package Low Temperature Thermostat.		0.04			<p>The Low Temperature Thermostat closes when the temperature of the crystal growth package drops to 85 °F (nominal). When the thermostat closes, power is supplied to relay K17A to close contacts K17 1/3 and complete a current path to the LAMP TEST switch S28 and to package and heater blanket heaters. The crewman throws switch S28 to the LO TEMP TEST position and receives an indication from LO TEMP light L10 that the package temperature has at some time gone below 85 °F. The operating range of the Low Temperature Thermostat is 85 °F (closes) to 100 °F (opens) \pm 5 °F.</p> <p>IIIb Failure of the Low Temperature Thermostat in the open position would have the following effect</p> <ul style="list-style-type: none"> • Communications and Data <ul style="list-style-type: none"> --An erroneous impression could be given of the temperature history of the crystal growth package (low temperature indication would be lost). <p>IIIb Failure of the Low Temperature Thermostat in the closed position would have the following effect</p> <ul style="list-style-type: none"> • Communications and Data <ul style="list-style-type: none"> --Same as failed open. <p>Indication of failure is by astronaut observation of the following:</p> <ul style="list-style-type: none"> • Failed open <ul style="list-style-type: none"> --LO TEMP light L10 illuminates when LAMP TEST switch S28 is placed in LAMP TEST, but does not illuminate when LAMP TEST switch S28 is switched to LO TEMP TEST, the crystal growth package is relatively cool to the touch • Failed closed <ul style="list-style-type: none"> --LO TEMP light L10 illuminates when LAMP TEST switch S28 is placed in LO TEMP TEST, but the crystal growth package is not relatively cool to the touch <p>References 8 and 9.</p>

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 14 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.5.2.4 Specify the P_{ft} of the M-555 Single Crystal Growth Package Heater Thermostat.		0.04		IIIa	<p>The Heater Thermostat controls power input to the crystal growth package heaters while the package is inside the experiment container. The operating range of the thermostat is 105 °F (closes) to 120 °F (opens) \pm 5 °F.</p> <p>If the Heater Thermostat failed in the open position, the following interfaces would be affected</p> <ul style="list-style-type: none"> • Electrical <ul style="list-style-type: none"> --Power could not be applied to the package heaters while the package was inside the experiment container (the Heater Thermostat is bypassed when the package is powered from the J6 connector in the work chamber). • Communications and Data <ul style="list-style-type: none"> --Lack of power to the package and heater blanket heaters could allow the gallium solution to freeze and degrade the crystal growth or rupture the ampoules and cause experiment termination
				IIIb	<p>If the Heater Thermostat failed closed, the following interface would be affected:</p> <ul style="list-style-type: none"> • Crew Safety <ul style="list-style-type: none"> --The crystal growth package would reach a higher than normal temperature, resulting in a possible burn to the crewman when he attempted to remove the package from the experiment container (Thermostats S29 and S30 would limit the temperatures of the experiment container interior and skin). <p>Indications of Heater Thermostat failure is by astronaut observation of the following:</p> <ul style="list-style-type: none"> • Failed open <ul style="list-style-type: none"> --LO TEMP light L10 illuminates when LAMP TEST switch S28 is placed in LO TEMP TEST. --The crystal growth package is relatively cool to the touch. • Failed closed <ul style="list-style-type: none"> --The crystal growth package is too hot to be held comfortably. <p>References 8 and 9.</p>
3.5.3 M-512 Facility.				N/A	Refer to functional items 3.5.3.1 and 3.5.3.2

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 15 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.5.3.1 Specify the P_{ft} of the Vacuum Work Chamber.				N/A	Refer to Appendix E, functional items 3.5.3.1, 3.5.3.2, 3.5.3.2.1, 3.5.3.3, 3.5.3.4, 3.5.3.5, and 3.5.3.9
3.5.3.2 Specify the P_{ft} of the Control Panel				N/A	Refer to functional items 3.5.3.2.1 through 3.5.3.2.14.
3.5.3.2.1 Specify the P_{ft} of POWER CONTROL AM BUS 1 circuit breaker CB4		0.02			POWER CONTROL AM BUS 1 circuit breaker CB4 is a push-pull circuit breaker with a 7.5 A capacity. The breaker receives AM Bus 1 power through the Line Filter and transfers it to the INSTRUMENTATION POWER switch S2 and the COMPOSITE CASTING POWER switch S25 for performance of Experiment M-555.
				IIIa	Failure of the circuit breaker CB4 in the open position would have the following effect: <ul style="list-style-type: none"> • Support <ul style="list-style-type: none"> --Performance of Experiment M-555 would be precluded since power could not be applied to the crystal growth package heaters for growth of the single crystal.
				IIIb	Failure of CB4 in the closed position would have no effect on the experiment, and would not be detectable unless the circuit breaker knob were frozen. <p>Indication of failure of POWER CONTROL AM BUS 1 circuit breaker CB4 is by astronaut observation of the following</p> <ul style="list-style-type: none"> • Failed open <ul style="list-style-type: none"> --No electrical functions for the M-512 facility control panel. Supporting indication of failure is by telemetry measurement M155-513 (AM Bus 1 Voltage) being between 24 and 30 Vdc. • Failed closed <ul style="list-style-type: none"> --No indication. <p>References 8 and 10.</p>

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 16 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.5 3 2.2 Specify the P_{ft} of CRYSTAL GROWTH HEATING PAD circuit breaker CB5.		0.02		IIIa	CRYSTAL GROWTH HEATING PAD circuit breaker CB5 is a push-pull circuit breaker with a 5 A capacity. The breaker receives AM Bus 1 power through the Line Filter and supplies it to the M-555 Single Crystal Growth Experiment Container heater circuitry for heating of the crystal growth package and sample ampoules while the package is installed in the container
				IIIa	Failure of the circuit breaker CB5 in the open position would affect the following interfaces <ul style="list-style-type: none"> ● Electrical <ul style="list-style-type: none"> --Failure of the circuit breaker CB5 in the open position would prevent power from being applied to the sample ampoules and M-555 Single Crystal Growth Experiment Container heater blanket Freezing of the liquid gallium in the ampoules could occur if the ampoule temperature dropped below 85 °F. ● Support <ul style="list-style-type: none"> --If the liquid gallium were to freeze, degradation of the single crystal growth data would occur, and the sample ampoules might rupture, causing termination of the experiment.
				IIIb	Failure of circuit breaker CB5 in the closed position would have the following effect <ul style="list-style-type: none"> ● Crew Safety <ul style="list-style-type: none"> --The crewman would disconnect the experiment container cable from the crystal growth package while the cable was conducting current. The amount of current is small (~ 1/4 A), however, and the probability of an arc occurring is small. This failure would be undetectable unless the circuit breaker knob were frozen. <p>Indication of failure of CRYSTAL GROWTH HEATING PAD AM BUS 1 circuit breaker CB5 is by astronaut observation of the following</p> <ul style="list-style-type: none"> ● Failed open <ul style="list-style-type: none"> --LO TEMP light L10 does not illuminate when LAMP TEST switch S28 is placed in the LAMP TEST position. --The crystal growth package is relatively cool to the touch. Supporting indication of failure is by telemetry measurement M155-513 (AM Bus 1 Voltage) being in the range of 24 to 30 Vdc

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 17 of 25)

Functional Block ~ Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.5 3.2.2 (Concluded)					<ul style="list-style-type: none"> Failed closed --No indication. <p>References 8 and 10.</p>
3.5 3.2.3 Specify the P_{ft} of the INSTRUMENTATION POWER switch S2		0.08		IIIb	<p>The INSTRUMENTATION POWER switch S2 is a three-position switch: BATT, OFF, and AM BUS 1. For Experiment M-555, the switch is placed in the AM BUS 1 position and receives AM Bus 1 power through POWER CONTROL AM BUS 1 circuit breaker CB4. The INSTRUMENTATION POWER switch S2 energizes the Power Supply Module for activation of INSTRUMENTATION TEMP gage M4 and INSTRUMENTATION PRESS gage M5. Pole 4-5-6 of switch S2 connects instrumentation to AM Bus 1 return.</p> <p>Failure of switch S2 in the OFF or BATT positions would have the following impacts:</p> <ul style="list-style-type: none"> Communications and Data <ul style="list-style-type: none"> --A loss of experiment data would occur (temperature recordings from INSTRUMENTATION TEMP gage M4). Crew Safety <ul style="list-style-type: none"> --The experiment operator would have to rely on the mission timeline for assurance that the crystal growth package had cooled sufficiently before attempting to remove the package from the work chamber. The pressure status of the work chamber would be unknown. <p>IIIb Failure of switch S2 in the AM BUS 1 position would have no impact on the experiment. Indication of failure of the INSTRUMENTATION POWER switch S2 is by astronaut observation of the following</p> <ul style="list-style-type: none"> Failed in OFF or BATT <ul style="list-style-type: none"> --No instrumentation functions, but work chamber floodlight illuminates when FLOOD LT switch S19 is moved to AM BUS 1. Failed in AM BUS 1 <ul style="list-style-type: none"> --INSTRUMENTATION TEMP gage M4 operates immediately when POWER CONTROL AM BUS 1 circuit breaker CB4 is closed <p>Reference 8.</p>

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Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.5.3 2.4 Specify the P_{ft} of the INSTRUMENTATION BASE TEMP °C switch S5		0.04		IIIb	<p>The INSTRUMENTATION BASE TEMP °C switch S5 is a nine-position rotary switch: 0, 100, 200, 400, 500, 600, 700, 800, and 900. This switch is used to select the appropriate temperature range as indicated by INSTRUMENTATION TEMP meter M4 to allow fine-range temperature readings from 0 to 999 °C in increments of 5 °C. The INSTRUMENTATION BASE TEMP °C switch S5 receives power from the INSTRUMENTATION BASE + METER switch S8 when switch S8 is placed in the BASE + METER position. The electrical signal is then routed to the applicable input of the Amplifier Module for readout on INSTRUMENTATION TEMP meter M4.</p> <p>Failure of the INSTRUMENTATION BASE TEMP °C switch S5 in any position would affect the following interface</p> <ul style="list-style-type: none"> • Communications and Data <ul style="list-style-type: none"> --A loss of experiment data would occur because of inability to take accurate temperature readings except when temperatures are in the range of the failed switch position. <p>Indication of failure of INSTRUMENTATION BASE TEMP °C switch S5 is by astronaut observation of a diminished range of fine temperature reading capability.</p> <p>References 8 and 11.</p>
3.5.3 2.5 Specify the P_{ft} of the INSTRUMENTATION BASE + METER switch S8.		0.08		IIIb	<p>The INSTRUMENTATION BASE + METER switch S8 is a two-position switch: METER X10 and BASE + METER. This switch receives power from the Power Supply Module, and transfers it (when in the BASE + METER position) to the INSTRUMENTATION BASE TEMP °C switch S5. When switch S8 is in the METER X10 position, the INSTRUMENTATION TEMP meter M4 displays temperatures from 0 to 999 °C in increments of 50 °C. When switch S8 is placed in the BASE + METER position, the INSTRUMENTATION TEMP meter M4 displays temperatures from 0 to 99 °C in increments of 5 °C, and these temperatures are then added by the experiment operator to the base temperature selected on INSTRUMENTATION BASE TEMP °C switch S5 to arrive at the fine temperature measurement.</p>
				IIIb	<p>Failure of the INSTRUMENTATION BASE + METER switch S8 in the BASE + METER position would cause no impact on the experiment.</p>
				IIIb	<p>If the switch failed in the METER X10 position, the following interface would be affected</p>

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Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.5 3 2.5 (Concluded)					<ul style="list-style-type: none"> • Communications and Data <ul style="list-style-type: none"> --A loss of fine temperature measurements would occur. <p>Indication of failure of INSTRUMENTATION BASE + METER switch S8 is by astronaut observation of the following</p> <ul style="list-style-type: none"> • Failed in BASE + METER <ul style="list-style-type: none"> --Rotation of the INSTRUMENTATION BASE TEMP °C switch S5 affects the reading on INSTRUMENTATION TEMP gage M4 if the temperature read by a particular thermocouple is high with respect to the setting of INSTRUMENTATION BASE TEMP °C switch S5. the INSTRUMENTATION TEMP Meter M4 will be pegger high; if the temperature is low with respect to the setting of switch S5, gage M4 will be pegged low, if the temperature is within range of the setting on switch S5, gage M4 will read somewhere between 0 and 99 °C. (During normal operation of INSTRUMENTATION BASE + METER switch S8, rotation of the INSTRUMENTATION BASE TEMP °C switch S5 does not affect the reading on gage M4 when switch S8 is in the METER X10 position). • Failed in METER X10 <ul style="list-style-type: none"> --Moving the switch lever to BASE + METER has no effect on the reading of INSTRUMENTATION TEMP gage M4 <p>References 8 and 11.</p>
3 5 3 2 6 Specify the P_{ft} of the INSTRUMENTATION TEMP SOURCE switch S9		0 08		IIb	<p>The INSTRUMENTATION TEMP SOURCE switch S9 is an eight-position rotary switch CHMBR WALL, CHMBR AIR, 1, 2, 3, 4, 5, and 6. This switch is used to select any of eight thermocouples that measure work chamber wall and air temperatures and M-555 Single Crystal Growth Package temperatures during performance of the experiment. The switch receives inputs from the thermocouples and sends the signals to the Amplifier Module for display on INSTRUMENTATION TEMP meter M4</p> <p>If the INSTRUMENTATION TEMP SOURCE switch S9 should fail in any position, the following interface would be affected</p> <ul style="list-style-type: none"> • Communications and Data <ul style="list-style-type: none"> --A loss of temperature measurements would occur

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 20 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.5.3 2.6 (Concluded)					Indication of failure of INSTRUMENTATION TEMP SOURCE switch S9 is by astronaut observation that rotation of the switch has no effect on the temperature measurement displayed on INSTRUMENTATION TEMP meter M4.
3.5.3.2.7 Specify the P_{ft} of the CRYSTAL GROWTH POWER switch S10 .		0.04			Reference 8.
				IIIa	The CRYSTAL GROWTH POWER switch S10 is a three-position switch: ON, OFF, and TEST. The switch receives power through the COMPOSITE CASTING POWER switch S25 that is in the OFF position. When switch S10 is placed in the TEST position, relay K18 is activated to close contacts K18 1/3 to apply 28 Vdc directly to the crystal growth package heaters (if any heater is defective, POWER CONTROL AM BUS 1 circuit breaker CB4 will open within 2 min). When switch S10 is moved to the ON position, relay K2 is energized to route the power through the 23-V regulator for growth of the gallium arsenide single crystal.
				IIIb	Failure of the CRYSTAL GROWTH POWER switch S10 in the OFF position will cause the following effect: <ul style="list-style-type: none"> • Support <ul style="list-style-type: none"> --Electrical power cannot be applied to the crystal growth package heaters. Loss of Experiment M-555 will occur.
				IIIb	Failure of the switch in TEST position will impact the following interface: <ul style="list-style-type: none"> • Communications and Data <ul style="list-style-type: none"> --Unregulated power will be applied to the crystal growth package heaters, causing degradation of the single crystal growth. (Growth of the crystal is closely dependent on temperature, and 28 V will cause the heater to operate outside satisfactory crystal growth temperature limits)
				IIIb	Failure of switch S10 in the ON position will cause the following impact to the experiment <ul style="list-style-type: none"> • Operability <ul style="list-style-type: none"> --POWER CONTROL AM BUS 1 circuit breaker CB4 will have to be opened to remove power from the crystal growth package. For taking temperature measurements, the circuit breaker will have to be closed and temperature measurements taken as quickly as possible to minimize the time that power is reapplied to the package.

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 21 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.5.3.2.7 (Concluded)					<p>Indication of failure of CRYSTAL GROWTH POWER switch S10 is by astronaut observation of the following:</p> <ul style="list-style-type: none"> • Failed OFF <ul style="list-style-type: none"> --Temperature of all crystal growth package thermocouples is less than 100 °F at the time of the first series of measurements (30 min after CRYSTAL GROWTH POWER switch S10 is placed in ON) • Failed in TEST <ul style="list-style-type: none"> --Temperatures of all crystal growth package thermocouples are abnormally high. • Failed ON <ul style="list-style-type: none"> --Temperatures of the package thermocouples remain high when the first series of measurements during the cooldown cycle are taken (30 min after CRYSTAL GROWTH POWER switch is placed in OFF). <p>Reference 8.</p>
3.5.3.2.8 Specify the P_{fi} of the COMPOSITE CASTING POWER switch S25.		0.04			<p>The COMPOSITE CASTING POWER switch S25 is a two-position switch: ON and OFF. Performance of Experiment M-555 requires that this switch be in the OFF position. Switch S25 receives power from AM Bus 1 through POWER CONTROL AM BUS 1 circuit breaker CB4, and, when in the OFF position, transfers the power to the CRYSTAL GROWTH POWER switch S10.</p> <p>IIIa Failure of the COMPOSITE CASTING POWER switch S25 in the ON position would impact the following interface:</p> <ul style="list-style-type: none"> • Support <ul style="list-style-type: none"> --Power could not be applied to the M-555 Single Crystal Growth Package for operation of the experiment, resulting in experiment termination. <p>IIIb Failure of the switch in the OFF position would have no effect on Experiment M-555.</p> <p>Indication of failure of the COMPOSITE CASTING POWER switch S25 is by astronaut observation of the following:</p>

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 22 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.5.3 2.8 (Concluded)					<ul style="list-style-type: none"> Failed ON <ul style="list-style-type: none"> --Same as CRYSTAL GROWTH POWER switch S10 failed OFF (refer to functional item 3.5.3.2 7). Failed OFF <ul style="list-style-type: none"> --No indication.
3.5 3 2.9 Specify the P_{ft} of relay K2.		0.05			<p>Reference 8.</p> <p>Relay K2 is energized when the CRYSTAL GROWTH POWER switch S10 is placed in the ON position. The relay closes contacts K2 4/6 and K2 1/3 to supply 28 Vdc to the 23-V regulator, and opens contacts K2 1/2 to prevent power from being supplied to the Composite Casting circuitry.</p> <p>IIIb Failure of relay K2 open would affect the following interface</p> <ul style="list-style-type: none"> Communications and Data <ul style="list-style-type: none"> --Regulated 23 Vdc could not be supplied to the crystal growth package heaters, thereby degrading experiment performance. By switching CRYSTAL GROWTH POWER switch S10 to TEST, 28 Vdc could be supplied to the package, but this would cause the package to operate at a higher temperature and would degrade experiment data. <p>IIIb Failure of relay K2 shorted would impact the following interface</p> <ul style="list-style-type: none"> Communications and Data <ul style="list-style-type: none"> --Same as failed open. <p>Indication of relay K2 failure is by astronaut observation of the following</p> <ul style="list-style-type: none"> Failed open <ul style="list-style-type: none"> --Same as CRYSTAL GROWTH POWER switch S10 failed OFF (refer to functional item 3.5.3.2 7). Failed shorted <ul style="list-style-type: none"> --POWER CONTROL AM BUS 1 circuit breaker CB4 may open when CRYSTAL GROWTH POWER switch S10 is placed in ON. --Same as CRYSTAL GROWTH POWER switch S10 failed OFF (refer to functional item 3.5.3.2 7).

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 23 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.5 3.2.9 (Concluded)					Reference 8.
3.5.3 2.10 Specify the P_{ft} of relay K18		0.05		IIIb	<p>Relay K18 is activated when the CRYSTAL GROWTH POWER switch S10 is placed in the TEST position. The relay closes contacts K18 1/3 to provide a path for 28 Vdc to be supplied to the crystal growth package heaters for testing of the heaters, and opens contacts K18 1/2 to enter diode CR37 into the 23-V regulator circuit. (The diode protects transistor Q30 from receiving 28 Vdc).</p> <p>Failure of relay K18 open or shorted would affect the following interface:</p> <ul style="list-style-type: none"> • Communications and Data <ul style="list-style-type: none"> --Testing of the crystal growth package heaters for integrity could not be performed, but the experiment could be performed. <p>Indication of failure of relay K18 is by astronaut observation of the following:</p> <ul style="list-style-type: none"> • Failed open <ul style="list-style-type: none"> --No indication. • Failed shorted <ul style="list-style-type: none"> --POWER CONTROL AM BUS 1 circuit breaker CB4 may open when CRYSTAL GROWTH POWER switch S10 is placed in TEST.
3.5 3 2.11 Specify the P_{ft} of the INSTRUMENTATION TEMP meter M4.		0.03		IIIb	<p>Reference 8.</p> <p>The INSTRUMENTATION TEMP meter M4 is activated by outputs from the Amplifier Module to display temperatures of the vacuum work chamber and M-555 Single Crystal Growth Package. The meter face is graduated from 0 to 99 °C in increments of 5 °C.</p> <p>Failure of the INSTRUMENTATION TEMP meter M4 would affect the following interfaces</p> <ul style="list-style-type: none"> • Communications and Data <ul style="list-style-type: none"> --Loss of experiment data (temperature recordings) would occur • Crew Safety <ul style="list-style-type: none"> --The experiment operator would have to rely on the mission timeline for assurance that the crystal growth package had cooled sufficiently before attempting to remove the package from the work chamber

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 24 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.5.3.2 11 (Concluded)					Indication of failure is by astronaut observation of the loss of the meter function References 8 and 11.
3.5.3.2.12 Specify the P_{ft} of the Power Supply Module.		0.04		IIIb	The Power Supply Module is activated by the INSTRUMENTATION POWER switch S2 and provides outputs for the INSTRUMENTATION PRESS meter M5, the INSTRUMENTATION BASE + METER switch S8, the work chamber air and wall thermocouples, and the M-555 Single Crystal Growth Package thermocouple reference junctions. Failure of the Power Supply Module to provide the correct outputs could affect the following interfaces <ul style="list-style-type: none"> • Communications and Data --Loss of temperature data could occur. • Crew Safety --The experiment operator would have to rely on the mission timeline for assurance that the crystal growth package had cooled sufficiently before attempting to remove the package from the work chamber. The pressure status of the work chamber would be unknown. Indication of failure is by astronaut observation of the loss of instrumentation functions. Reference 8
3.5.3.2.13 Specify the P_{ft} of the Amplifier Module.		0.04		IIIb	The Amplifier Module receives inputs from the INSTRUMENTATION TEMP SOURCE switch S9 and the INSTRUMENTATION BASE TEMP °C switch S5 and provides an output to the INSTRUMENTATION TEMP meter M4. Failure of the Amplifier Module to provide a correct output signal would cause an impact on the following interfaces: <ul style="list-style-type: none"> • Communications and Data --Loss of temperature data would occur • Crew Safety --The experiment operator would have to rely on the mission timeline for assurance that the crystal growth package had cooled sufficiently before attempting to remove the package from the work chamber.

TABLE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH PRE-FLIGHT OPERATIONS EVALUATION ANALYSIS (Sheet 25 of 25)

Functional Block Number and Title	Expected Range and Dimension of Variables			Criticality Category Number	Remarks
	min	nom	max		
3.5 3 2.13 (Concluded)					Indication of failure is by astronaut observation of either erroneous measurements or no measurements displayed on INSTRUMENTATION TEMP meter M4.
3.5 3 2.14 Specify the P_{ft} of the 23-V Regulator		0.05		IIIb	<p>Reference 8</p> <p>The 23-V regulator receives a 28-V input when the CRYSTAL GROWTH POWER switch S10 is placed in the ON position, and converts the input to a 23-V output to the crystal growth package heaters for experiment operation.</p> <p>Failure of the regulator would cause the following interface to be affected:</p> <ul style="list-style-type: none"> • Communications and Data <ul style="list-style-type: none"> --The required 23-V input for satisfactory growth of the gallium arsenide single crystal would not be provided, experiment data would be degraded. <p>Indication of failure is by astronaut observation of unexpected crystal growth package temperatures in conjunction with telemetry measurement M155-513 within the range of 26 to 30 Vdc.</p> <p>References 8 and 10.</p>

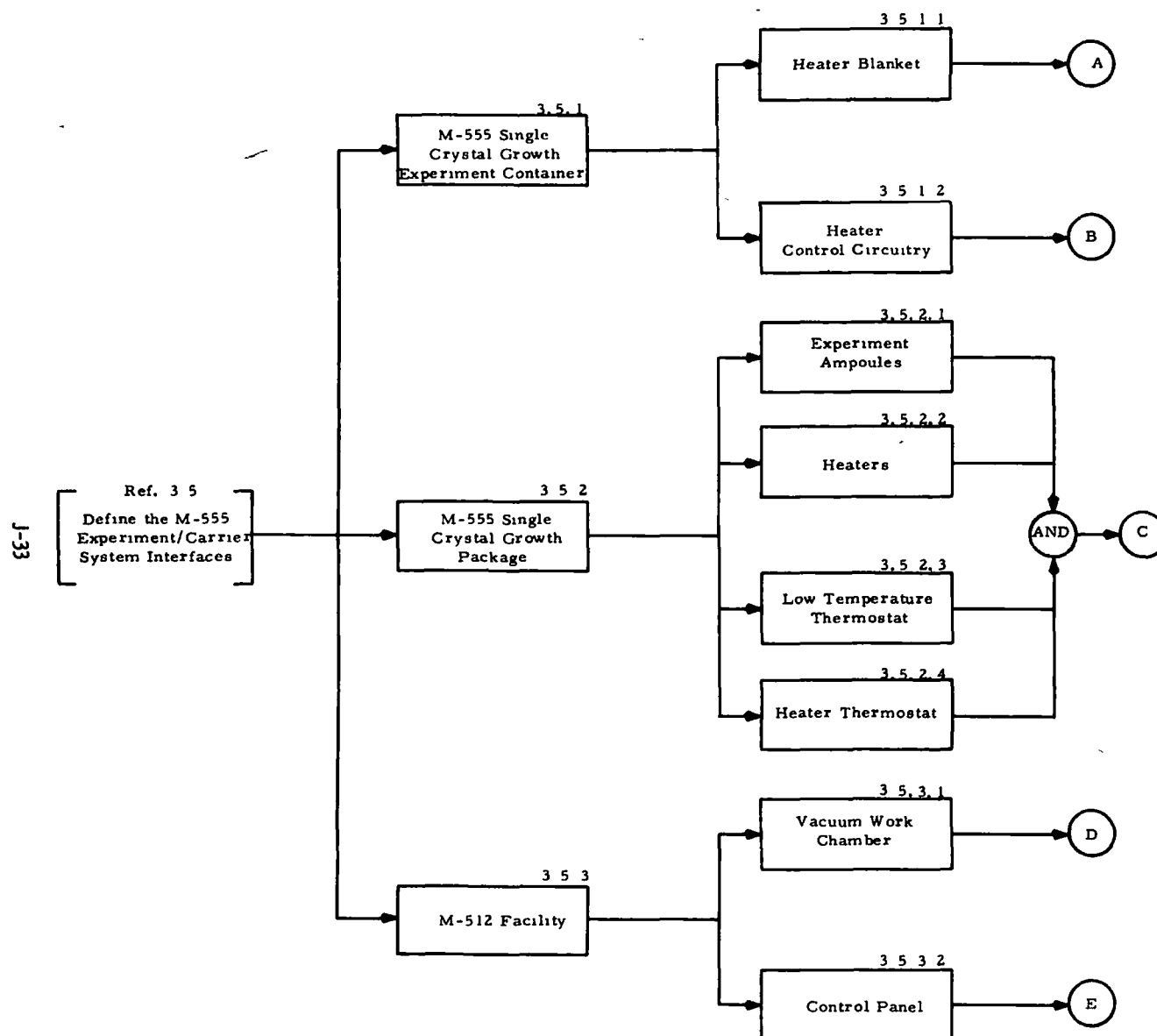


FIGURE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH FUNCTIONAL BLOCK DIAGRAM (Sheet 1 of 4)

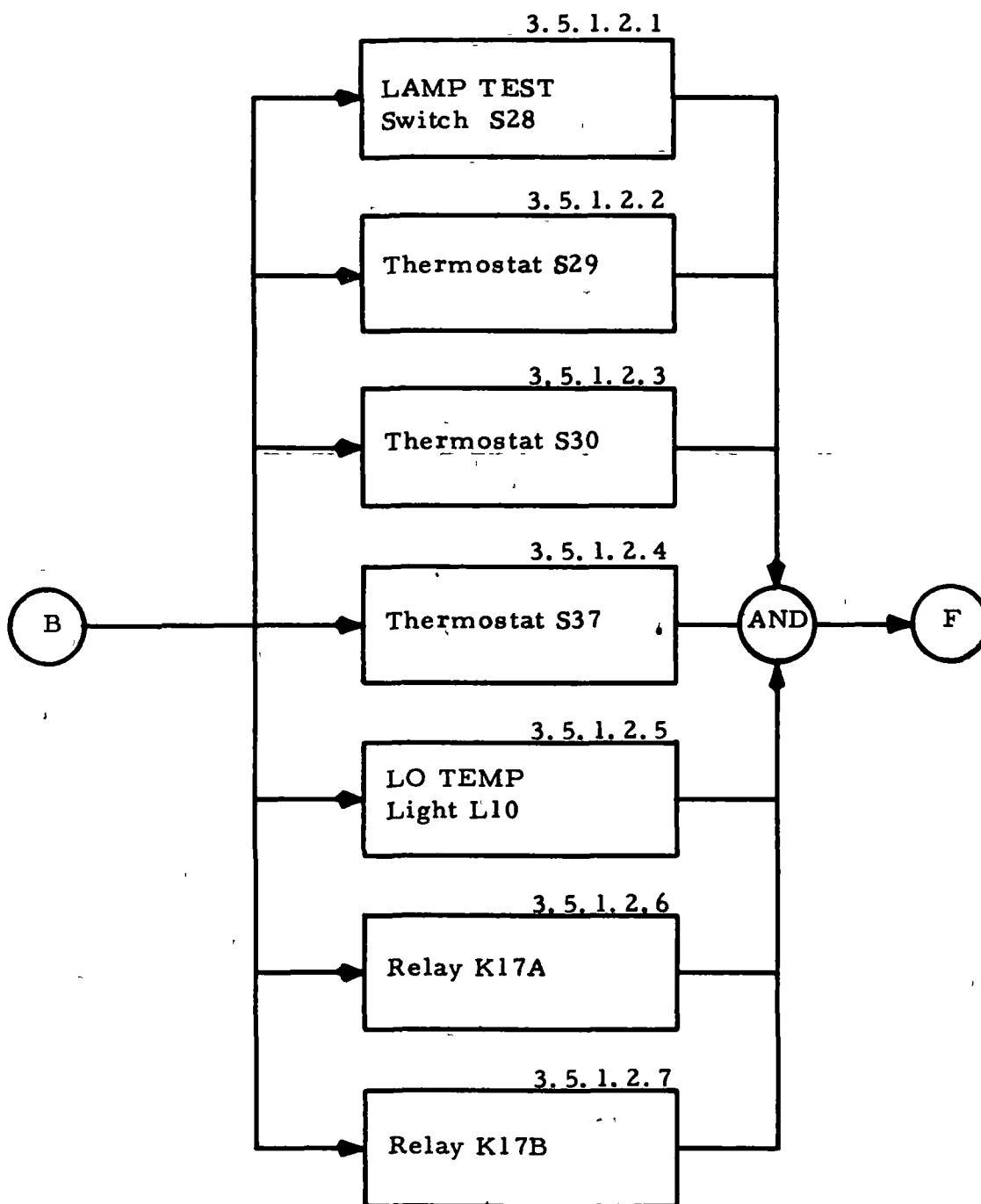


FIGURE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH FUNCTIONAL BLOCK DIAGRAM (Sheet 2 of 4)

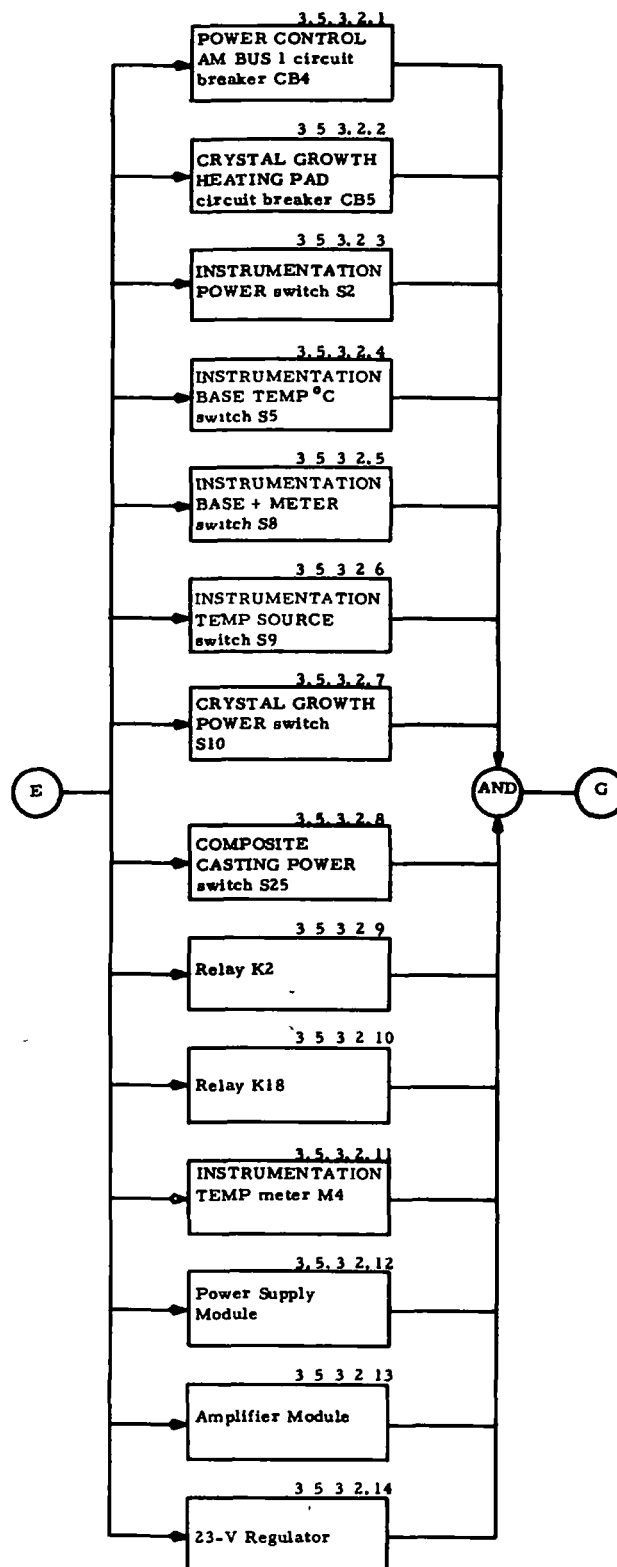


FIGURE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH FUNCTIONAL BLOCK DIAGRAM (Sheet 3 of 4)

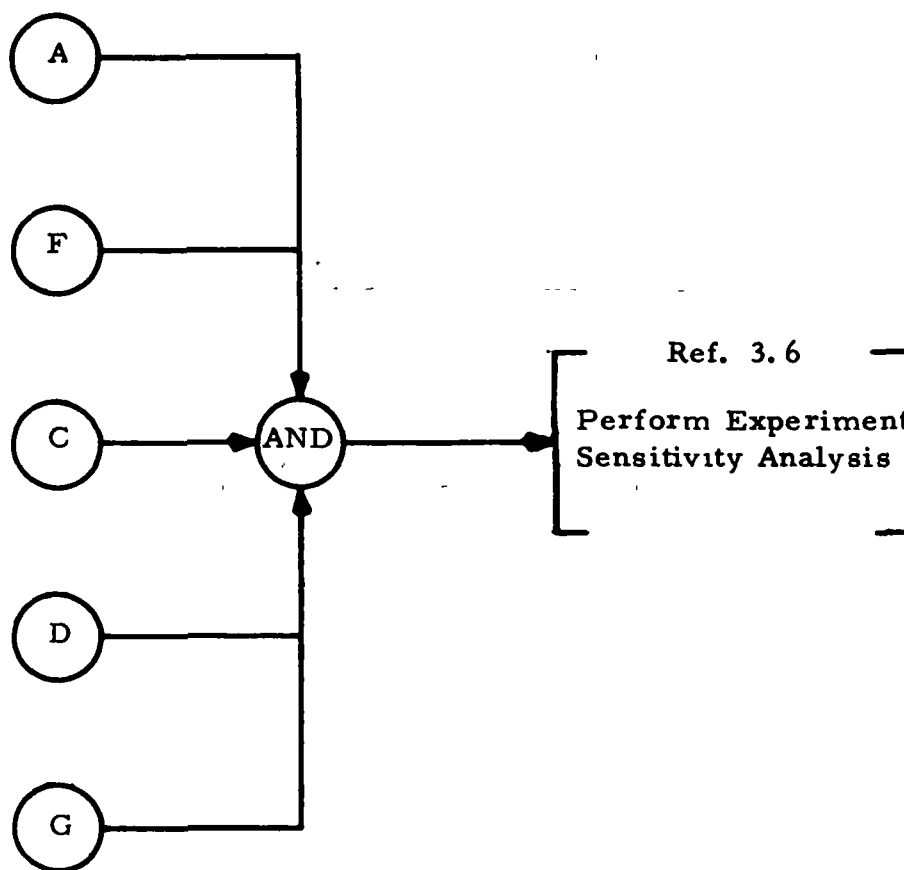
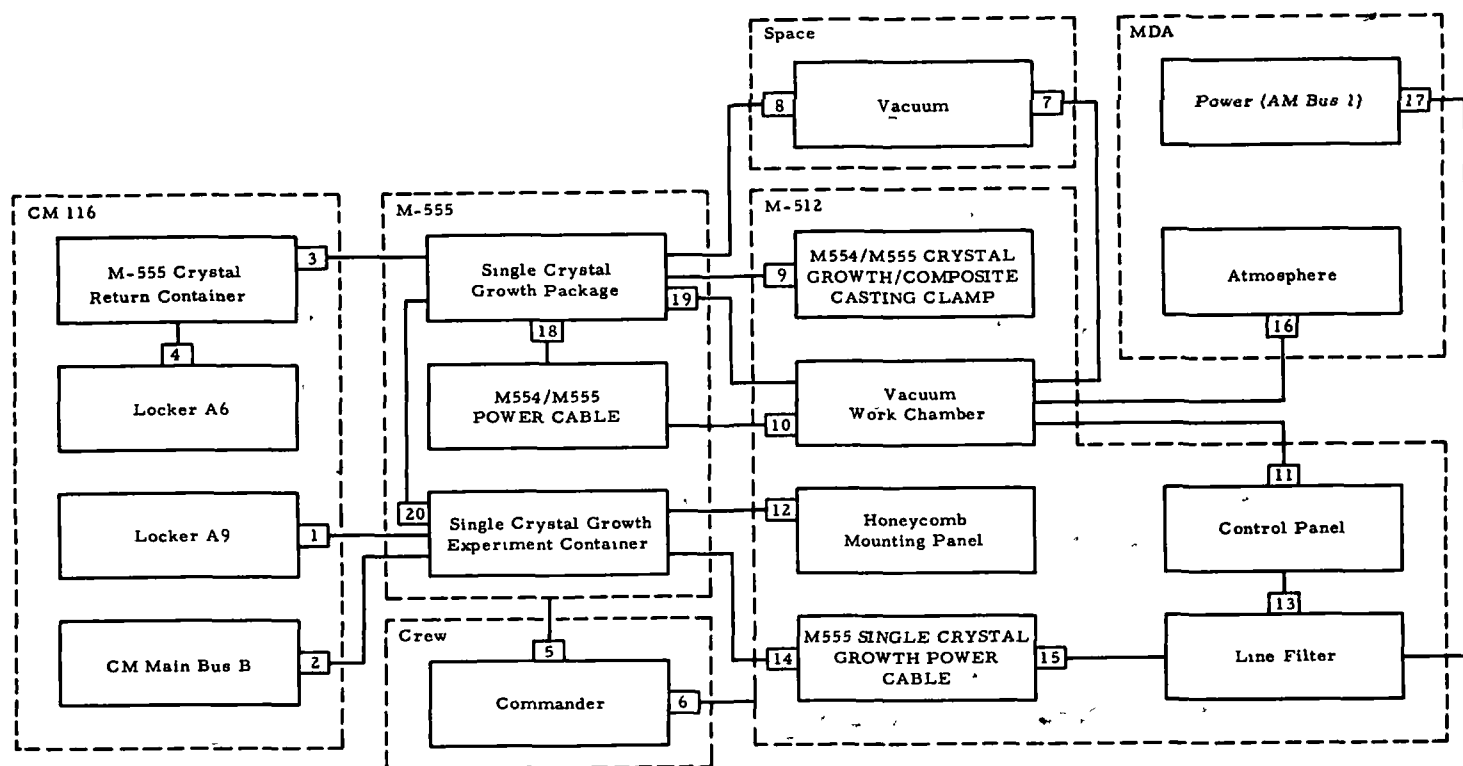


FIGURE J-1. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH FUNCTIONAL BLOCK DIAGRAM (Sheet 4 of 4)

SECTION II.

**EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL
GROWTH INTERFACE BLOCK DIAGRAM AND DEFINITION**

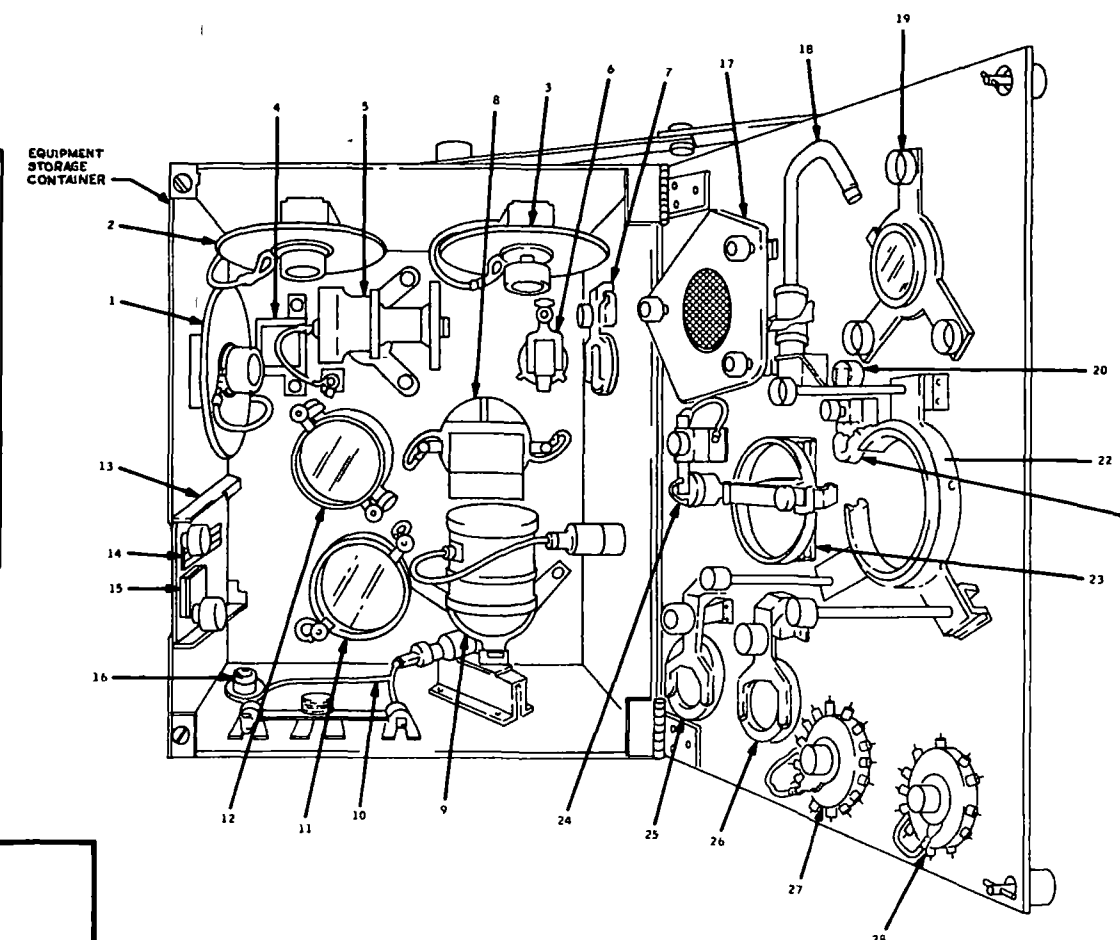
FIGURE J-2
EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE
CRYSTAL GROWTH INTERFACE BLOCK DIAGRAM
AND DEFINITION



Code	Measurement No	Remarks
1	Voice Comments	There is a mechanical interface between CM Locker A9 and the M-555 Single Crystal Growth Container. The container is stowed in Locker A9 prior to launch and remains there until it is removed by the crew to the MDA after docking and mounted on the M-512 Materials Processing Facility.
2	CC0207V and CM onboard display (voltage gage M10 and current gage M9 on CM panel MDC 3 - See Reference 12)	There is an electrical interface between CM Main Bus B and the M-555 Single Crystal Growth Experiment Container. Main Bus B provides electrical power (28 ± 2 Vdc) to the container through UTIL LEB MNB (CB83) circuit breaker on panel MDC 5, UTILITY POWER (S6) switch on panel LEB 100, and a cable provided by the CM. The cable is connected to the J5 connector on panel LEB 100 and runs through a hole in Locker A9 to the M-555 Single Crystal Growth Experiment Container J47 connector. The experiment container requires an average of 7 W from the CM, and will not exceed 10 W max with 30 Vdc peak voltage. The Experiment M-555 energy use in the CM shall not exceed 1.7 kW-hr for a specific mission (Reference 13).
3	Voice Comments	There is a mechanical interface between the M-555 Crystal Return Container and the M-555 Single Crystal Growth Package. The package is stowed inside the return container for return to earth.
4	Voice Comments	There is a mechanical interface between the CM Locker A6 and the M-555 Crystal Return Container. The return container, containing the processed crystal growth package, is stowed in CM Locker A6 for return to earth.
5	Voice Comments	There is an operational interface between the Commander and Experiment M-555. The Commander is required to remove the M-555 Single Crystal Growth Experiment Container from the CM to the MDA and to mount it on the M-512 facility and apply AM Bus 1 power. For experiment operation, he is required to remove the M-555 Single Crystal Growth Package from the container, install it in the M-512 work chamber heat sink, connect the package power cable to the package and to the work chamber J6 receptacle, and to secure the package to the heat sink with the M554/M555 CRYSTAL GROWTH/COMPOSITE CASTING CLAMP. For experiment termination, he is required to remove the package from the heat sink and to stow the crystal growth package in the CM for return to earth.
6	Voice Comments	There is an operational interface between the Commander and the M-512 Materials Processing Facility. During Experiment M-555 performance, he is required to operate the necessary M-512 facility valves, switches, and circuit breakers to obtain a vacuum in the work chamber and to apply power to the crystal growth package for growing the crystals.
7	Voice Comments (onboard display - INSTRUMENTATION PRESS gage M5 on M-512 facility control panel)	There is an environmental interface between space vacuum and the M-512 facility work chamber. For operation of Experiment M-555, the work chamber and bulkhead vent valves are opened, exposing the interior of the work chamber to vacuum.
8	Voice Comments	There is an environmental interface between space vacuum and the M-555 Single Crystal Growth Package. The package vent cap is opened for experiment operation to expose the interior of the package to vacuum to prevent oxidation of the package insulation. (Oxidation of the insulation would allow excessive heat loss through the package walls and could prevent the package from attaining a sufficiently high temperature for growth of the crystals.)
9	Voice Comments	There is a mechanical interface between the M554/M555 CRYSTAL GROWTH/COMPOSITE CASTING CLAMP and the M-555 Single Crystal Growth Package. The clamp is placed around the package flange and secured to the work chamber heat sink adapter to hold the package in intimate thermal contact with the heat sink.
10	Voice Comments M155-513	There is an electrical interface between the M-512 facility work chamber and the M554/M555 POWER CABLE. Electrical power (28 ± 2 Vdc) from AM Bus 1 is provided to the cable at the work chamber J6 connector.
11	Voice Comments M155-513	There is a mechanical interface between the M-512 facility work chamber and the M554/M555 POWER CABLE. The power cable zero-g connector is mechanically mated to the work chamber J6 connector for operation of Experiment M-555.
12	Voice Comments	There is an electrical interface between the M-512 facility control panel and work chamber. The switches and circuit breakers on the control panel distribute and control AM Bus 1 power to the work chamber J6 connector during Experiment M-555 operation. The control panel also contains the necessary displays used to determine work chamber pressure and temperature status.
13	M155-513	There is a mechanical interface between the M-512 facility honeycomb mounting panel and the M-555 Single Crystal Growth Experiment Container. After the container is moved from the CM, and before Experiment M-555 operation in the work chamber, the container is mounted on the honeycomb mounting panel with two Calfax fasteners.
14	Voice Comments M155-513	There is an electrical interface between the M-512 facility line filter and the control panel. The line filter receives AM Bus 1 power, conditions it, and supplies it to the control panel for distribution to the work chamber J6 connector and temperature and pressure transducers.
15	Voice Comments M155-513	There is an electrical interface between the M555 SINGLE CRYSTAL GROWTH POWER CABLE and the M-555 Single Crystal Growth Experiment Container. The cable provides electrical power (28 ± 2 Vdc) from the M-512 facility line filter to the container when the container is mounted on the M-512 facility honeycomb mounting panel prior to Experiment M-555 operation.
16	N/A	There is a mechanical interface between the M555 SINGLE CRYSTAL GROWTH POWER CABLE and the M-555 Single Crystal Growth Experiment Container. The power cable P47 connector is connected to the container J47 receptacle by the crewman when the container is moved from the CM to the M-512 facility and attached to the honeycomb mounting panel.
17	M155-513	There is an electrical interface between the M555 SINGLE CRYSTAL GROWTH POWER CABLE and the M-512 facility line filter. The line filter supplies AM Bus 1 power to the cable through CRYSTAL GROWTH HEATING PAD AM BUS 1 circuit breaker CB5.
18	Voice Comments M155-513	There is an environmental interface between the MDA atmosphere and the M-512 facility work chamber. The work chamber is required to be evacuated for performance of Experiment M-555, therefore, one work chamber volume of MDA atmosphere (approximately 1.8 ft ³) is lost during Experiment M-555.
19	Voice Comments	There is an electrical interface between AM Bus 1 power and the M-512 facility line filter. The bus supplies power to the line filter through M512 circuit breaker located on AM panel 202. Experiment M-555 requires 28 ± 2 Vdc while the experiment container is mounted on the M-512 facility honeycomb mounting panel (this power maintains the gallium solution in the experiment ampoules in a liquid state), and 28 ± 2 Vdc when the experiment package is mounted in the work chamber heat sink for growth of the crystals.
20	Voice Comments (onboard display - LO TEMP light L10 located on the M-555 Single Crystal Growth Experiment Container) M155-513	There is an electrical interface between the M-555 Single Crystal Growth Package and the M554/M555 POWER CABLE. The power cable provides electrical power from the work chamber J6 connector to the package heaters for growth of the crystals. Approximately 11,270 W-hr of energy at 28 ± 2 Vdc is required for growing the single crystals (average 98 W x 115 hr).
	Voice Comments	There is a mechanical interface between the M-555 Single Crystal Growth Package and the M554/M555 POWER CABLE. The crewman is required to connect the P36 connector of the power cable to the J36 connector on the package for experiment operation.
	Voice Comments	There is a mechanical interface between the M-555 Single Crystal Growth Package and the M-512 facility work chamber. The package is installed inside the work chamber heat sink for Experiment M-555 operation, with the package heat extraction flange in secure thermal contact with the heat sink adapter.
	Voice Comments (onboard display - LO TEMP light L10)	There is an electrical interface between the M-555 Single Crystal Growth Experiment Container and the M-555 Single Crystal Growth Package. When the package is installed in the container, the container power cable supplies CM Main Bus B power (when in the CM) or AM Bus 1 power (when in the MDA) to maintain the gallium arsenide solution of the package sample ampoules in a liquid state. While in the container, the package requires an average of 7 W from the CM and approximately 3 W from AM Bus 1.
	Voice Comments	There is a mechanical interface between the M-555 Single Crystal Growth Experiment Container and the M-555 Single Crystal Growth Package. Prior to experiment operation the package is stowed in the container, with the container power cable P48 connector connected to the package J36 connector, the package is surrounded by the container heater blanket.
	Voice Comments	There is an environmental interface between the M-555 Single Crystal Growth Experiment Container and the M-555 Single Crystal Growth Package. The container heater blanket and control circuitry is required to assist the package heaters in maintaining the package sample ampoule temperature above 85 °F to prevent freezing of the gallium arsenide solution.

SECTION III.

EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL
GROWTH SYSTEMS DIAGRAM



- 1 WELD SPECIMEN 1
- 2 WELD SPECIMEN 2
- 3 WELD SPECIMEN 3
- 4 DEFLECTION MIRROR
- 5 ELECTRON BEAM WELD MOTOR
- 6 CAMERA MIRROR
- *7 FLOOD LIGHT SHIELD
- 8 HATCH VIEW PORT MIRROR
- 9 SPHERE FORMING MOTOR
- 10 WATER SPRAY NOZZLES
- 11 HATCH VIEW PORT SHIELD FLAMMABILITY
- 12 HATCH VIEW PORT SHIELD SPHERE FORMING
- 13 BATTERY ACCESS PANEL
- 14 COMPOSITE CASTING SPECIMEN STORAGE
- 15 TOOL STORAGE
- *16 WATER SPRAY CONNECTION COVER
- *17 ELECTRON BEAM COVER
- 18 FLAMMABILITY SPECIMEN HOLDER
- 19 HEAT SINK COVER
- 20 SPHERE CATCHER 1
- 21 SPHERE CATCHER 2
- *22 CRYSTAL GROWTH OR COMPOSITE CASTING CLAMP
- *23 WORK CHAMBER VENT FILTER 1 and 2
- 24 SPHERE CATCHER INSTALLATION TOOL
- 25 CAMERA PORT SHIELD-SPHERE FORMING
- 26 CAMERA PORT SHIELD-FLAMMABILITY
- 27 SPHERE FORMING SPECIMEN 1
- 28 SPHERE FORMING SPECIMEN 2

*Used for Experiment M-555 or installed in the M-512 work chamber during experiment performance.

► All Materials Processing Facility associated switches, circuit breakers, lights, and valves are listed as being common to MDA panel 105. The exceptions are the 4-in. vent valves. These are MDA hardware.

2 See Figure J-3.

► M-555 Single Crystal Growth Experiment Container circuit details shown on Figure J-3.

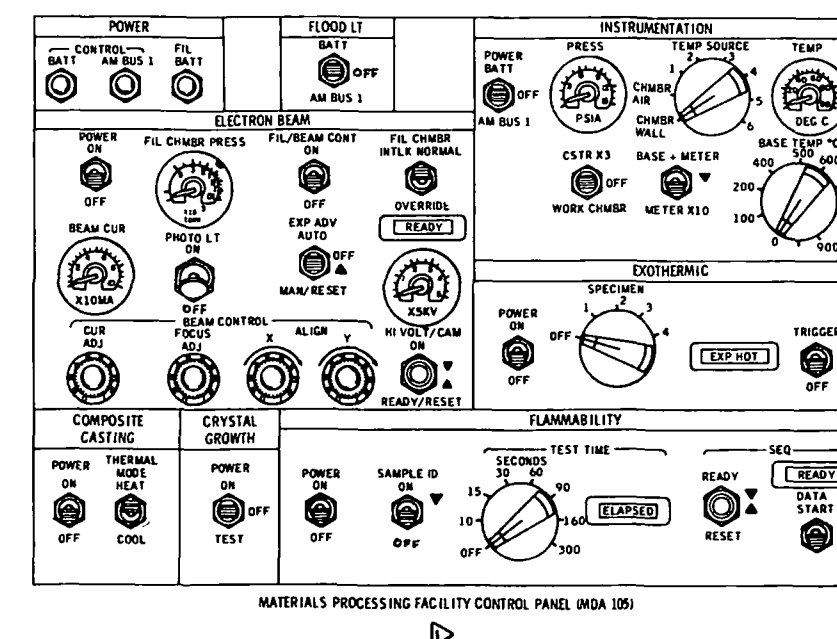
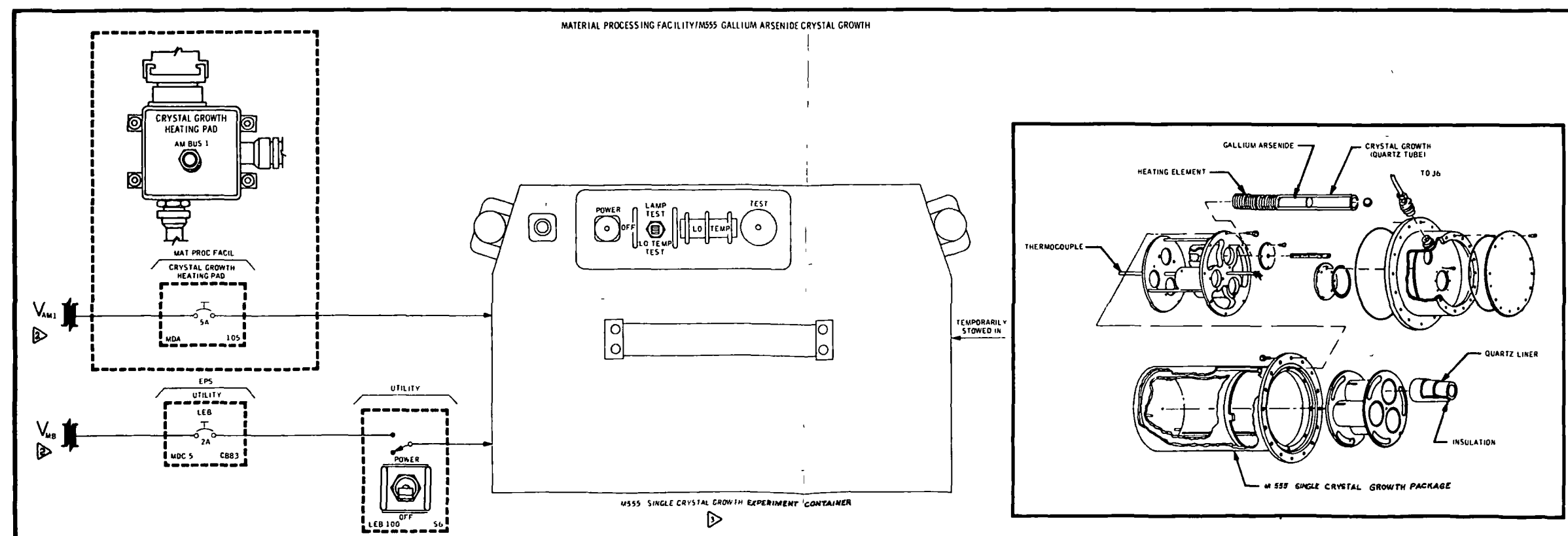


FIGURE J-4. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MECHANICAL AND FLUID SYSTEMS DIAGRAM

SECTION IV.

EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL
GROWTH DATA REQUIREMENTS SUMMARY

TABLE J-II. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH
DATA REQUIREMENTS SUMMARY

Measurement Name	Range And Dimension of Variables	Measurement No.	Telemetry Assignment Channel	Data Return	Data Time	Remarks
<ul style="list-style-type: none"> ● Astronaut Voice Comments <ul style="list-style-type: none"> --Voice loop --Voice transcripts --Crew debriefing transcripts ● Crew Log ● Volt AM Bus No. 1 Voltage 	N/A N/A N/A N/A 15 to 35 Vdc	N/A N/A N/A N/A M155-513	N/A N/A N/A N/A WP1B154A30HC56	Intermittent N/A N/A N/A Continuous	Real All All All Real	GOSS

SECTION V.

EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL
GROWTH DATA REQUEST FORMS

The data required for evaluation of Experiment M-555 consist only of crew voice comments, the experiment log book, and the AM Bus 1 voltage level during experiment performance. Data Request Forms (DRF) have been submitted to obtain these data; therefore, a DRF requesting these data specifically for Experiment M-555 is not necessary.

SECTION VI.

EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL
GROWTH ENGINEERING CHANGE REQUESTS

No Engineering Change Requests are recommended for Experiment M-555.

SECTION VII.

EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL
GROWTH EVALUATION SEQUENCE

TABLE J-III. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH EVALUATION SEQUENCE (Sheet 1 of 12)

<u>Assignments</u>		<u>Conditions</u>	<u>Requirements</u>																						
Mission	• SL-1/SL-2	Crew	Functional Objectives																						
Orbital Assembly	• MDA (M-512 facility)	Experiment	• FO-1 Perform growth of single crystals and collect data and samples for return to earth																						
Carrier	• SL-2 (CM Locker A9 - Launch) (CM Locker A6 - Return)	Ground Support																							
		<ul style="list-style-type: none"> The experiment setup and termination will be performed by one crewman (commander) This experiment must be performed on SL-1/SL-2 because it is necessary to retain the pretask samples in the molten state, and provisions have been integrated only in the SL-2 CM and the MDA to support this requirement The operation time will be 115 hr, unmanned, except for periodic temperature monitoring by one crewman The experiment apparatus containing the crystal specimens will be removed from the vacuum chamber and stowed in the CM. One vacuum chamber cycle will be required for operation of the experiment See ground support (prelaunch) below. 																							
		<ul style="list-style-type: none"> Prelaunch Power must be applied to the single crystal growth container heater blanket and package heaters to maintain the samples in a molten state. Power disruptions cannot be longer than those indicated below to maintain ampoules between 85 and 95 °F 																							
		<table border="1"> <thead> <tr> <th rowspan="2">Crystal Growth Package</th><th rowspan="2">Average Ambient Air Temperature</th><th colspan="2">Max Time Unpowered</th></tr> <tr> <th>Recommended</th><th>Absolute</th></tr> </thead> <tbody> <tr> <td>Out of Container</td><td>--</td><td>3 min</td><td>--</td></tr> <tr> <td>In Container</td><td>40 °F</td><td>20 min</td><td>40 min</td></tr> <tr> <td>In Container</td><td>50 °F</td><td>30 min</td><td>1 hr 02 min</td></tr> <tr> <td>In Container</td><td>70 °F</td><td>55 min</td><td>1 hr 48 min</td></tr> </tbody> </table>	Crystal Growth Package	Average Ambient Air Temperature	Max Time Unpowered		Recommended	Absolute	Out of Container	--	3 min	--	In Container	40 °F	20 min	40 min	In Container	50 °F	30 min	1 hr 02 min	In Container	70 °F	55 min	1 hr 48 min	
Crystal Growth Package	Average Ambient Air Temperature	Max Time Unpowered																							
		Recommended	Absolute																						
Out of Container	--	3 min	--																						
In Container	40 °F	20 min	40 min																						
In Container	50 °F	30 min	1 hr 02 min																						
In Container	70 °F	55 min	1 hr 48 min																						
		<ul style="list-style-type: none"> Flight N/A Post-Flight No non-standard facilities for recovery of the crystal samples and transport to the PI are required 																							

<u>Experiment/Evaluation Team - Key Personnel Locator</u>		
<u>Name</u>	<u>Responsibility</u>	<u>Office Address, Symbol, and Telephone Number</u>
Mr. M. C Davidson	Principal Investigator (PI)	MSFC, Bldg 4331, S&E-SSL-TR, 205-453-3090
Dr Martin Rubenstein	Experiment Developer (ED)	Westinghouse Central Research Labs, Pittsburgh, Pennsylvania, 412-256-3515
Mr. E O Walker	MSFC Experiment Manager (EM)	MSFC, Bldg 4201, PM-SL-DP, 205-453-3183
Mr. A W Bearskin	S&E Integration Engineer (IE)	MSFC, Bldg 4610, S&E-ASTN-SDI, 205-453-3811
Mr B. R. Aldrich	S&E Experiment Engineer (EE)	MSFC, Bldg 4711, S&E-PE-MXX, 205-453-2010
Mr W. R Bock	Technical Discipline Manager (TDM)	MSFC, Bldg 4610, S&E-ASTN-SDF, 205-453-3810
Mr M S Byers	Experiment Operations Engineer (EOE)	Teledyne Brown Engineering Company, Huntsville, Alabama, 205-532-1612
Mr S. Buzzard	Experiment Integration Engineer (EIE)	Martin Marietta Corporation, Denver, Colorado, 303-794-5211, ext 5451
Mr C. Gruby	Experiment Flight Controller (EFC)	MSC/FC4, Houston, Texas, 713-483-4717

TABLE J-III. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH EVALUATION SEQUENCE (Sheet 2 of 12)

Operation Step Number*	Crewman**	Test Procedure	Evaluation (Check One)		See Contingency Plan Number	Remarks
			Satisfactory	Anomaly		
P - 60 min GMT 12 10 SL-1/SL-2 Mission Day 140	TP	Experiment Evaluation Team manned and available. Contact Experiment M-555 Technical Discipline Manager, S&E-ASTN-SD- HOSC Telephone No. 205-453-2200, ext. 311, Astronautics Laboratory Telephone No. 205-453-3810. Reference: Skylab Flight Plan SL-2, Summary and Detail Timelines, MSC-0362S, latest revision, and MDA Experiment Checklist and Log, MSC, latest revision.				
GMT 13 10 SL-1/SL-2 Mission Day 140		Commence Experiment Preparation.				
P 1.0		M-512 Materials Processing Facility Verification.				
P 1.1		Install M-512 foot restraint.				Foot restraint stowage M127
P 1.2		Unlatch control panel cover and open to operating position.				
P 1.3		Obtain logbook, checklist, and clipboard.				Logbook stowage M126 Checklist stowage M126 Clipboard stowage M126
P 1.4		Attach checklist and logbook to clipboard and secure to control panel cover.				
P 1.5		cb M512 - closed (up) (verify).				cb M512 is located on STS panel 202.
P 1.6		Work chamber vent vlv - CLOSE (verify).				
P 1.7		Bulkhead vent vlv - CLOSE (verify).				
P 1.8		FILAMENT CHAMBER VENT vlv - CLOSE (verify).				
P 1.9		CHAMBER REPRESS vlv - CLOSED (verify).				

*P - Preparation
O - Operations
T - Termination
L - Lift-off (Booster)

**TP - Test Pilot (Commander).
OBS - Observer (Science Pilot)
PLT - Pilot
ALL - TP/OBS/PLT

TABLE J-III. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH EVALUATION SEQUENCE (Sheet 3 of 12)

Operation Step Number*	Crewman**	Test Procedure	Evaluation (Check One)		See Contingency Plan Number	Remarks
			Satisfactory	Anomaly		
P 1.10		SYSTEM PURGE vlv - CLOSED (verify).				
P 1.11		WATER ACCUMULATOR FILL vlv - CLOSED (verify).				
P 1.12		WATER SPRAY vlv - CLOSED (verify).				
P 1.13		Work chamber hatch closed and latched (verify).				
P 1.14		M512 BAT. VENT vlv - OPEN (verify).				
P 1.15		cb MAIN BATTERY (CB1) - closed (verify).				
P 1.16		cb BATTERY DISCHARGE (CB6) - closed (verify).				
P 1.17		Verify the following on the M-512 facility control panel.				
P 1.17.1		cb POWER CONTROL BATT (CB2) - open				
P 1.17.2		cb POWER CONTROL AM BUS 1 (CB4) - open				
P 1.17.3		cb POWER FIL BATT (CB3) - open				
P 1.17.4		FLOOD LT (S19) - OFF				
P 1.17.5		INSTRUMENTATION POWER (S2) - OFF				
P 1.17.6		INSTRUMENTATION TEMP SOURCE (S9) - CHMBR WALL				
P 1.17.7		ELECTRON BEAM POWER (S3) - OFF				
P 1.17.8		FIL/BEAM CONT (S12) - OFF				
P 1.17.9		FIL CHMBR INTLK (S13) - NORMAL				
P 1.17.10		INSTRUMENTATION CSTR X3 (S1) - OFF				
P 1.17.11		INSTRUMENTATION BASE + METER (S8) - METER X10				

*P - Preparation

O - Operations

T - Termination

L - Lift-off (Booster)

**TP - Test Pilot (Commander)

OBS - Observer (Science Pilot)

PLT - Pilot

ALL - TP/OBS/PLT

TABLE J-III. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH EVALUATION SEQUENCE (Sheet 4 of 12)

Operation Step Number*	Crewman**	Test Procedure	Evaluation (Check One)		See Contingency Plan Number	Remarks
			Satisfactory	Anomaly		
P 1.17.12		INSTRUMENTATION BASE TEMP °C (S5) - 0				
P 1.17.13		PHOTO LT (S4) - OFF				
P 1.17.14		EXP ADV (S16) - OFF				
P 1.17.15		HI VOLT/CAM (S14) - off (center)				
P 1.17.16		EXOTHERMIC POWER (S15) - OFF				
P 1.17.17		EXOTHERMIC SPECIMEN (S7) - OFF				
P 1.17.18		EXOTHERMIC TRIGGER (S6) - OFF				
P 1.17.19		COMPOSITE CASTING POWER (S25) - OFF				
P 1.17.20		COMPOSITE CASTING THERMAL MODE (S26) - HEAT				
P 1.17.21		CRYSTAL GROWTH POWER (S10) - OFF				
P 1.17.22		FLAMMABILITY POWER (S21) - OFF				
P 1.17.23		FLAMMABILITY SAMPLE ID (S20) - OFF				
P 1.17.24		FLAMMABILITY TEST TIME SECONDS (S22) - OFF				
P 1.17.25		FLAMMABILITY SEQ READY (S18) - off (center)				
P 1.17.26		FLAMMABILITY SEQ DATA (S17) - off (down).				
P 1.18		cb CRYSTAL GROWTH HEATING PAD AM BUS 1 (CB5) - closed (verify).				CB5 is located on the Line Filter box between the EQUIPMENT STORAGE CONTAINER and the M-512 facility control panel.
P 1.19		cb BATTERY DISCHARGE (CB6) - open.				Experiment M-555 should not be performed with CB6 closed.

*P - Preparation
 O - Operations
 T - Termination
 L - Lift-off (Booster)

**TP - Test Pilot (Commander)
 OBS - Observer (Science Pilot)
 PLT - Pilot
 ALL - TP/OBS/PLT

TABLE J-111. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH EVALUATION SEQUENCE (Sheet 5 of 12)

Operation Step Number*	Crewman**	Test Procedure	Evaluation (Check One)		See Contingency Plan Number	Remarks
			Satisfactory	Anomaly		
P 2.0		Obtain lightweight headset and CCU. Setup SIA to record voice data.				Headset stowage: M157 CCU stowage: M124
P 2.1		Disconnect M554/M555 POWER CABLE from the M-518 Multipurpose Electric Furnace package (leave zero-g connector mated to the dummy connector on the M-512 honeycomb mounting panel).				
P 2.2		LAMP TEST (S28) - LAMP TEST (LO TEMP lt L10 on).			P22A1	LAMP TEST switch S28 is located on the M-555 Single Crystal Growth Experiment Container. LO TEMP lt L10 is also on the container.
P 2.3		LAMP TEST (S28) - LO TEMP TEST (Monitor LO TEMP lt L10)			P23A1	
		<u>NOTE</u> If LO TEMP lt L10 illuminates, this indicates that the crystal growth package temperature has at some time dropped below 85°F. If the light illuminates, voice record and log the occurrence.				
P 2.4		CHAMBER REPRESS vlv - OPEN.			P24A1	
P 2.5		Open work chamber hatch.				
P 2.6		cb CRYSTAL GROWTH HEATING PAD AM BUS 1 (CB5) - open.			P26A1	CB5 is located on the Line Filter box between the EQUIPMENT STORAGE CONTAINER and the M-512 facility control panel.

*P - Preparation

O - Operations

T - Termination

L - Lift-off (Booster)

**TP - Test Pilot (Commander)

OBS - Observer (Science Pilot)

PLT - Pilot

ALL - TP/OBS/PLT

TABLE J-III. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH EVALUATION SEQUENCE (Sheet 6 of 12)

Operation Step Number*	Crewman**	Test Procedure	Evaluation (Check One)		See Contingency Plan Number	Remarks
			Satisfactory	Anomaly		
		<p><u>NOTE</u></p> <p>When the experiment container is opened with power removed, the allowable time before power must be reapplied is 18 min. With the package installed in the work chamber heat sink, power must be reapplied within 2 min.</p>				
P 2.7		Open M-555 Single Crystal Growth Experiment Container.				
P 2.8		Fold the two halves of the heater blanket away from the M-555 Single Crystal Growth Package.				
P 2.9		Remove the M-555 Single Crystal Growth Package from container and disconnect container electrical cable from package.				
P 2.10		Remove M554/M555 POWER CABLE from dummy connector and connect to the M-555 Single Crystal Growth Package.			P210A1	
P 2.11		Install M-555 Single Crystal Growth Package into work chamber heat sink.				
P 2.12		Connect M554/M555 POWER CABLE zero-g connector to M-512 work chamber power receptacle.			P212A1	
P 2.13		Open M-555 Single Crystal Growth Package vent cap.			P213A1	
P 2.14		cb POWER CONTROL AM BUS 1 (CB4) - close.				
P 2.15		CRYSTAL GROWTH POWER (S10) - ON.				
P 2.16		INSTRUMENTATION POWER (S2) - AM BUS 1.				
P 2.17		INSTRUMENTATION CSTR X3 (S1) - WORK CHMBR (Verify 5 psia on INSTRUMENTATION PRESS gage M5).			P217A1	

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T - Termination

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TABLE J-III. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH EVALUATION SEQUENCE (Sheet 7 of 12)

Operation Step Number*	Crewman**	Test Procedure	Evaluation (Check One)		See Contingency Plan Number	Remarks
			Satisfactory	Anomaly		
P 2 18		Remove M554/M555 CRYSTAL GROWTH/COMPOSITE CASTING CLAMP from the EQUIPMENT STORAGE CONTAINER and install around M-555 Single Crystal Growth Package			P218A1 P218B1	
P 2 19		Close and latch work chamber hatch			P219A1	
P 2.20		CHAMBER REPRESS vlv - CLOSED			P220A1	
P 2.21		Work chamber vent vlv - OPEN.			P24A1 P210A2	
P 2.22		Bulkhead vent vlv - OPEN.			P24A1 P210A2	
P 2.23		CRYSTAL GROWTH POWER (S10) - TEST (2 min). <u>NOTE:</u> The crystal growth power test is to confirm the integrity of the crystal growth package heaters, the POWER CONTROL AM BUS 1 circuit breaker CB4 should not open; if it does, this indicates a malfunctioning heater.			P223A1 P210A2	
P 2.24		Verify 0 psia on INSTRUMENTATION PRESS gage M5.			P224A1 P224A2	
P 2.25		Close and latch M-555 Single Crystal Growth Experiment Container				

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OBS - Observer (Science Pilot)
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TABLE J-111. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH EVALUATION SEQUENCE (Sheet 8 of 12)

Operation Step Number ^a	Crewman ^{**}	Test Procedure	Evaluation (Check One)		See Contingency Plan Number	Remarks
			Satisfactory	Anomaly		
GMT 13:20 SL-1/SL-2 Mission Day 140	TP	Commence experiment operation.				
O 1.0		CRYSTAL GROWTH POWER (S10) - ON.				
		<u>NOTE</u> Temperature recordings are taken every 30 min for the first 3 hr of the 115-hr heating cycle. Temperature recordings for the first 3 hr begin 30 min after Operation Step No. O 1.0.				
O 1.1		INSTRUMENTATION TEMP SOURCE (S9) - 1.				
O 1.2		INSTRUMENTATION BASE TEMP °C (S5) - range as indicated by INSTRUMENTATION TEMP meter M4.			O12A1 O12B1	
O 1.3		INSTRUMENTATION BASE + METER (S8) - BASE + METER (mom) <u>NOTE</u> Reading on INSTRUMENTATION TEMP gage M4 when INSTRUMENTATION BASE + METER switch S8 is in BASE + METER position is added to the setting on INSTRUMENTATION BASE TEMP °C switch S5 to obtain the actual temperature.			O13A1 O13B1 O13C1	
O 1.4		Record temperature reading in log and on SIA.				
O 1.5		Repeat Operation Step Nos. O 1.1 through O 1.4 for INSTRUMENTATION TEMP SOURCE (S9) positions 2 through 6.				

*P - Preparation

O - Operations

T - Termination

L - Lift-off (Booster)

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OBS - Observer (Science Pilot)

PLT - Pilot

ALL - TP/OBS/PLT

TABLE J-III. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH EVALUATION SEQUENCE (Sheet 9 of 12)

Operation Step Number*	Crewman**	Test Procedure	Evaluation (Check One)		See Contingency Plan Number	Remarks
			Satisfactory	Anomaly		
O 1.6	TP	INSTRUMENTATION POWER (S2) - OFF.				Headset stowage: M157 CCU stowage: M124
O 1.7		Stow lightweight headset and CCU.				
O 2.0		Single Crystal Growth Temperature Record (12 hr).				
		<u>NOTE.</u>				
		Temperatures are recorded every 12 hr during the last 112 hr of the 115-hr heating cycle.				
O 2.1		Obtain lightweight headset and CCU.				Headset stowage M157 CCU stowage: M124
O 2.2		INSTRUMENTATION POWER (S2) - AM BUS 1.				
O 2.3		INSTRUMENTATION TEMP SOURCE (S9) - 1.				
O 2.4		INSTRUMENTATION BASE TEMP °C (S5) - range as indicated by INSTRUMENTATION TEMP gage M4.			O12A1 O12B1	
O 2.5		INSTRUMENTATION BASE + METER (S8) - BASE + METER (mom).			O13A1 O13B1 O13C1	
O 2.6		Record reading in log and on SIA.				
O 2.7		Repeat Operation Step Nos. O 2.3 through O 2.6 for INSTRUMENTATION TEMP SOURCE (S9) positions 2 through 6.				
O 2.8		INSTRUMENTATION POWER (S2) - OFF.				

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TABLE J-III. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH EVALUATION SEQUENCE (Sheet 10 of 12)

Operation Step Number*	Crewman**	Test Procedure	Evaluation (Check One)		See Contingency Plan Number	Remarks
			Satisfactory	Anomaly		
O 2.9	TP	Stow lightweight headset and CCU.				Headset stowage: M157 CCU stowage: M124
O 3.0		Initiate Crystal Growth Cooling Cycle.				
O 3.1		INSTRUMENTATION POWER (S2) - AM BUS 1.				
O 3.2		CRYSTAL GROWTH POWER (S10) - OFF.				
		<u>NOTE</u> Log time of turning off CRYSTAL GROWTH POWER (S10). The 9-hr cooldown time starts. Temperatures are recorded every 30 min for the first 3 hr of the 9-hr cooling cycle.				
O 3.3		Work chamber vent vlv - CLOSE.			P220A1 O33A1	
O 3.4		Bulkhead vent vlv - CLOSE.			P220A1 O33A1	
O 3.5		CHAMBER REPRESS vlv - OPEN.			P24A1	
		<u>CAUTION</u> =====				
		Do not proceed until chamber and MDA pressures have equalized as indicated by the INSTRUMENTATION PRESS gage M5.				
O 3.6		CHAMBER REPRESS vlv - CLOSED.			P220A1 O33A1	
O 3.7		Obtain lightweight headset and CCU.				Headset stowage: M157 CCU stowage: M124

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TABLE J-III. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH EVALUATION SEQUENCE (Sheet 11 of 12)

Operation Step Number*	Crewman**	Test Procedure	Evaluation (Check One)		See Contingency Plan Number	Remarks
			Satisfactory	Anomaly		
O 3.8	TP	INSTRUMENTATION TEMP SOURCE (S9) - 1.				
O 3.9		INSTRUMENTATION BASE TEMP °C (S5) - range as indicated by INSTRUMENTATION TEMP meter M4.			O39A1 O12B1	
O 3.10		INSTRUMENTATION BASE + METER (S8) - BASE + METER (mom).			O13A1 O13B1 O13C1	
O 3.11		Record reading in log and on SIA.				
O 3.12		Repeat Operation Step Nos. O 3.8 through O 3.11 for INSTRUMENTATION TEMP SOURCE (S9) positions 2 through 6.				
O 3.13		INSTRUMENTATION POWER (S2) - OFF.				
O 3.14		cb POWER CONTROL AM BUS 1 (CB4) - open.				
O 3.15		Stow lightweight headset and CCU.				Headset stowage M157 CCU stowage M124
GMT 14 40 SL-2 Mission Day 145		Commence Experiment Termination. <u>CAUTION</u>				
		Do not proceed to Operation Step No. T 1.0 until the 9-hr cooldown time has elapsed.				
T 1.0		CHAMBER REPRESS vlv - OPEN.				
T 1.1		Open work chamber hatch.				

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T - Termination

L - Lift-off (Booster)

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PLT - Pilot

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TABLE J-III. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH EVALUATION SEQUENCE (Sheet 12 of 12)

Operation Step Number*	Crewman**	Test Procedure	Evaluation (Check One)		See Contingency Plan Number	Remarks
			Satisfactory	Anomaly		
T 1.2		Remove M554/M555 CRYSTAL GROWTH/COMPOSITE CASTING CLAMP from work chamber and stow in EQUIPMENT STORAGE CONTAINER.				
T 1.3		Disconnect M554/M555 POWER CABLE zero-g connector from work chamber power receptacle.				
T 1.4		Remove M554/M555 POWER CABLE from the crystal growth package and reconnect to the M-518 Multipurpose Electric Furnace package and the dummy connector on the M-512 honeycomb mounting panel.				
T 1.5		Remove M-555 Single Crystal Growth Package from work chamber heat sink and stow in CM Locker A6 inside M-512 Crystal Container.				M-512 Crystal Container is launched in CM Locker A3 inside M071/M073 Sample Container.
T 1.6		Close and latch work chamber hatch.				
T 1.7		CHAMBER REPRESS vlv - CLOSED.				
T 1.8		INSTRUMENTATION TEMP SOURCE (S9) - CHMBR WALL.				
T 1.9		INSTRUMENTATION BASE TEMP °C (S5) - 0.				
T 1.10		INSTRUMENTATION CSTR X3 (S1) - OFF.				
T 1.11		Remove logbook, checklist, and clipboard from M-512 control panel cover and stow.				Logbook stowage M126 Checklist stowage M126 Clipboard stowage M126
T 1.12		Close and latch M-512 control panel cover.				
T 1.13		Remove and stow M-512 foot restraint.				Foot restraint stowage M127

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SECTION VIII.

EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL
GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE

TABLE J-IV. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE - EXPERIMENT PREPARATION (P) (Sheet 1 of 9)

Operation Step Number	Experiment/Crew Tasks	Possible Malfunction	Contingency Plan	Remarks (malfunctions, corrections, results)
P 2.2	LAMP TEST (S28) - LAMP TEST (LO TEMP lt L10 on)	P22A LO TEMP lt L10 fails to illuminate	P22A1 Recycle LAMP TEST switch S28, and continue.	<p>The following failures could cause the malfunction:</p> <ul style="list-style-type: none"> • LAMP TEST switch S28 failed OFF • LAMP TEST switch S28 failed in LO TEMP TEST and temperature of crystal growth package has not gone below 85 °F • LO TEMP light L10 shorted (the light consists of two bulbs in parallel). • CRYSTAL GROWTH HEATING PAD AM BUS 1 circuit breaker CB5 open. • M512 circuit breaker open (AM panel 202). • Relay K17A shorted and crystal growth package temperature is below 85 °F.
P 2.3	LAMP TEST (S28) - LO TEMP TEST (Monitor LO TEMP lt L10)	P23A LO TEMP light L10 illuminates.	P23A1 Voice record and log the occurrence of the illumination of LO TEMP light L10	<p>This is not, actually, a malfunction but indicates a lack of sufficient power to the crystal growth package to maintain its temperature above 85 °F. Possible failures which would cause the light to illuminate are as follows:</p> <ul style="list-style-type: none"> • Experiment container left unpowered long

P

TABLE J-IV. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE - EXPERIMENT PREPARATION (P) (Sheet 2 of 9)

Operation Step Number	Experiment/Crew Tasks	Possible Malfunction	Contingency Plan	Remarks (malfunctions, corrections, results)
P 2.3 (Concluded)				<p>enough for the crystal growth package to cool to 85 °F. (See Sheet 1 of Table J-III for times)</p> <ul style="list-style-type: none"> • Open circuit in experiment container heater blanket. • Thermostat S29 failed open. • Thermostat S30 failed open. • Crystal growth package low temperature thermostat failed closed. • Crystal growth package heater thermostat failed open.
P 2.4	CHAMBER REPRESS vlv - OPEN	P24A CHAMBER REPRESS valve fails CLOSED.	<p>P24A1 Apply a greater amount of torque to the valve knob to force the valve to open.</p> <p>P24A2 Remove vacuum cleaner port cover to vent chamber interior to MDA pressure.</p>	
P 2.6	cb CRYSTAL GROWTH HEATING PAD AM BUS 1 (CB5) - open.	P26A CB5 will not open. Knob is frozen.	P26A1 Open cb M512, open experiment container and disconnect container cable from crystal growth package Reset cb M512 and continue.	

P

TABLE J-IV. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE - EXPERIMENT PREPARATION (P) (Sheet 3 of 9)

Operation Step Number	Experiment/Crew Tasks	Possible Malfunction	Contingency Plan	Remarks (malfunctions, corrections, results)
P 2.10	Remove M554/M555 POWER CABLE from dummy connector and connect to the M-555 Single Crystal Growth Package.	P210A M554/M555 POWER CABLE cannot be connected to the crystal growth package	P210A1 Check connector pins on crystal growth package and straighten if bent. Use pin straightener. P210A2 Terminate Experiment M-555.	Pin straightener stowage E623, drawer 2B.
P 2.12	Connect M554/M555 POWER CABLE zero-g connector to M-512 work chamber power receptacle	P212A M554/M555 POWER CABLE cannot be connected to the M-512 work chamber power receptacle	P212A1 Check pins on zero-g connector of M554/M555 POWER CABLE and straighten if bent. Use pin straightener. Refer to the following contingency plan <ul style="list-style-type: none">• P210A2.	Pin straightener stowage E623, drawer 2B.
P 2.13	Open M-555 Single Crystal Growth Package vent cap.	P213A Vent cap will not open.	P213A1 Obtain vise grip pliers and use to force the vent cap open. Refer to the following contingency plan <ul style="list-style-type: none">• P210A2	Vise grip pliers stowage E623, drawer 2B.
P 2.17	INSTRUMENTATION CSTR X3 (S1) - WORK CHMBR. (Verify 5 psia on INSTRUMENTATION PRESS gage M5)	P217A INSTRUMENTATION PRESS gage M5 reads 0 psia.	P217A1 Recycle INSTRUMENTATION CSTR X3 switch S1 P217A2 Tap on gage face with finger. P217A3 Verify INSTRUMENTATION TEMP gage M4 is functional (reading greater than 0 °C). <ul style="list-style-type: none">• If gage M4 is operating, refer to the following contingency plan --P217A4.	

P

TABLE J-IV. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE - EXPERIMENT PREPARATION (P) (Sheet 4 of 9)

Operation Step Number	Experiment/Crew Tasks	Possible Malfunction	Contingency Plan	Remarks (malfunctions, corrections, results)
P 2.17 (Continued)			<ul style="list-style-type: none"> If gage M4 is not operating, refer to the following contingency plan: --P217A5. <p>P217A4 Place INSTRUMENTATION CSTR X3 switch S1 in CSTR X3 and monitor INSTRUMENTATION PRESS gage M5 for operation.</p> <ul style="list-style-type: none"> If gage M5 operates, a malfunction of the work chamber pressure transducer or INSTRUMENTATION CSTR X3 switch S1 is indicated. Continue the experiment. If gage M5 does not operate, a malfunction of INSTRUMENTATION CSTR X3 switch S1 or INSTRUMENTATION PRESS gage M5 is indicated. Continue the experiment. <p>P217A5 Verify POWER CONTROL AM BUS 1 circuit breaker CB4 and M512 circuit breaker are closed by switching FLOOD LT switch S19 to AM BUS 1.</p> <ul style="list-style-type: none"> If the floodlight illuminates, refer to the following contingency plan: --P217A6. If the floodlight does not illuminate, refer to the following contingency plan. --P217A7. 	<p>INSTRUMENTATION PRESS gage M5 reading should be about 8 (corresponds to actual Electron Beam Gun canister pressure of 24 psia) with switch S1 in CSTR X3</p> <p>The FIL CHMBR PRESS gage M3 may be used to verify vacuum in the work chamber if the Auxiliary Power Junction Vacuum Gauge Cable is obtained and used to supply AM Bus 1 power to gage M3. The cable is stowed in location M157.</p>

P

TABLE J-IV. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE - EXPERIMENT PREPARATION (P) (Sheet 5 of 9)

Operation Step Number	Experiment/Crew Tasks	Possible Malfunction	Contingency Plan	Remarks (malfunctions, corrections, results)
P 2.17 (Concluded)			<p>P217A6 Recycle INSTRUMENTATION POWER switch S2, and monitor the INSTRUMENTATION PRESS gage M5 and INSTRUMENTATION TEMP gage M4</p> <ul style="list-style-type: none"> • If the gages operate, continue the experiment. • If the gages do not operate, a malfunction is indicated in either the INSTRUMENTATION POWER switch S2 or the Power Supply Module. The experiment may be performed, but all temperature data for the experiment will be lost. <p>P217A7 Recycle POWER CONTROL AM BUS 1 circuit breaker CB4 and M512 circuit breaker and monitor the INSTRUMENTATION PRESS gage M5 and INSTRUMENTATION TEMP gage M4</p> <ul style="list-style-type: none"> • If the gages operate, continue the experiment. • If the gages do not operate, a malfunction is indicated in either the POWER CONTROL AM BUS 1 circuit breaker CB4 or the M512 circuit breaker. The experiment will be terminated 	<p>Refer to the immediately preceding Remark for contingency plan P217A4.</p>

P

TABLE J-IV. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE - EXPERIMENT PREPARATION (P) (Sheet 6 of 9)

Operation Step Number	Experiment/Crew Tasks	Possible Malfunction	Contingency Plan	Remarks (malfunctions, corrections, results)
P 2.18	Remove M554/M555 CRYSTAL GROWTH/COMPOSITE CASTING CLAMP from the EQUIPMENT STORAGE CONTAINER and install around M-555 Single Crystal Growth Package.	P218A Clamp cannot be installed securely. P218B Clamp cannot be installed	P218A1 Tighten clamp as much as possible and continue. P218B1 Secure crystal growth package in work chamber heat sink by using pressure sensitive tape across the connector end of the package and the work chamber.	Intimate thermal contact between the work chamber heat sink adapter and the crystal growth package flange must be maintained for proper heat transfer between the package and the heat sink Tape stowage: E623 and M144.
P 2.19	Close and latch work chamber hatch	P219A One or more of the three Calfax fasteners and three cam-lock latches cannot be tightened securely.	P219A1 Tighten as many of the Calfax fasteners and cam-lock latches as possible and attempt to evacuate the work chamber. Monitor the INSTRUMENTATION PRESSURE gage M5 to verify that the work chamber pressure is zero. A decision will have to be made whether or not to perform the experiment, based on the level of vacuum that can be maintained in the work chamber.	Experiment M-555 requires a vacuum to prevent oxidation of the reflective insulation in the crystal growth package. If the insulation is oxidized, its ability to retain heat in the package will be degraded, and this will cause the package to require more power for proper growth of the crystals. The experiment could be performed without a 1×10^{-4} torr vacuum if the amount of MDA atmosphere lost due to a leak were acceptable.
P 2.20	CHAMBER REPRESS vlv - CLOSED	P220A CHAMBER REPRESS valve fails OPEN.	P220A1 Apply a greater amount of torque to the valve knob to force the valve to close P220A2 Plug end of repressurization line exterior to the chamber with an appropriate object and secure it with pressure-sensitive tape. Perform a vacuum integrity check of the chamber. If vacuum integrity is verified, continue. Remove vacuum cleaner port cover to repressurize the work chamber after the experiment	Refer to P219A Remarks. The repressurization line diameter is 1/4 in. Pressure-sensitive tape is stowed in locations M144 and E623, drawer 2A.

TABLE J-IV. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE - EXPERIMENT PREPARATION (P) (Sheet 7 of 9)

Operation Step Number	Experiment/Crew Tasks	Possible Malfunction	Contingency Plan	Remarks (malfunctions, corrections, results)
P 2.20 (Concluded)			Refer to the following contingency plan: <ul style="list-style-type: none"> • P210A2 	
P 2.21	Work chamber vent vlv - OPEN.	P221A Work chamber vent valve fails in CLOSE position	Refer to the following contingency plans <ul style="list-style-type: none"> • P24A1 • P210A2. 	
P 2.22	Bulkhead vent vlv - OPEN.	P222A Bulkhead vent valve fails in CLOSE position	Refer to the following contingency plans <ul style="list-style-type: none"> • P24A1 • P210A2 	
P 2.23	CRYSTAL GROWTH POWER (S10) - TEST (2 min)	P223A POWER CONTROL AM BUS 1 circuit breaker CB4 opens immediately P223B POWER CONTROL AM BUS 1 circuit breaker CB4 does not open immediately, but opens within 2 min	P223A1 Switch CRYSTAL GROWTH POWER switch S10 to OFF, reset POWER CONTROL AM BUS 1 circuit breaker CB4, place CRYSTAL GROWTH POWER switch S10 in ON, and continue. Refer to the following contingency plan <ul style="list-style-type: none"> • P210A2 	If CB4 opens immediately when CRYSTAL GROWTH POWER switch S10 is placed in TEST, this could indicate a shorted relay K18. If relay K18 is failed, the experiment can be continued, but the heater integrity test cannot be performed. This would indicate one or more malfunctioning crystal growth package heaters. Leakage of the gallium arsenide solution out of the quartz ampoules into the heater coils would short the heaters.
P 2.24	Verify 0 psia on INSTRUMENTATION PRESS gage M5	P224A INSTRUMENTATION PRESS gage M5 remains at 5 psia.	P224A1 Recycle INSTRUMENTATION CSTR X3 switch S1 P224A2 Tap on gage M5 face with finger.	

P

TABLE J-IV. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE - EXPERIMENT PREPARATION (P) (Sheet 8 of 9)

Operation Step Number	Experiment/Crew Tasks	Possible Malfunction	Contingency Plan	Remarks (malfunctions, corrections, results)
P 2.24 (Continued)			<p>P224A3 Close work chamber and bulkhead vent valves, and open CHAMBER REPRESS valve.</p> <ul style="list-style-type: none"> • If the work chamber can be heard repressurizing, a malfunction is indicated in the work chamber pressure transducer or in the INSTRUMENTATION PRESS gage M5. Close CHAMBER REPRESS valve, open work chamber and bulkhead vent valves, and continue the experiment. • If the work chamber cannot be heard repressurizing, open the hatch, remove and inspect the vent filter. <ul style="list-style-type: none"> --If the filter is visibly clogged, clean it, replace it in the vent line, evacuate the chamber and continue. --If the filter cannot be cleaned sufficiently, continue the experiment without the filter in the vent line. --If the filter is not visibly clogged, a malfunctioning work chamber pressure transducer or INSTRUMENTATION PRESS gage M5 is indicated. <p>Refer to the following contingency plans</p> <ul style="list-style-type: none"> • P224A1 • P224A2 	<p>Refer to second Remark for contingency plan P217A4.</p> <p>Use the pick tool on the Swiss army knife (stowage locations E625 and E623, drawer 2C) or a piece of wire (stowage location E623, drawer 2A) to clean the meshes of the filter.</p>
		P224B INSTRUMENTATION PRESS gage M5 reading stabilizes between 0 and 5 psia.		

P

TABLE J-IV. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE - EXPERIMENT PREPARATION (P) (Sheet 9 of 9)

Operation Step Number	Experiment/Crew Tasks	Possible Malfunction	Contingency Plan	Remarks (malfunctions, corrections, results)
P 2.24 (Concluded)			<p>P224B1 Close work chamber vent valve and monitor the INSTRUMENTATION PRESS gage M5</p> <ul style="list-style-type: none"> • If the gage reading does not vary, a faulty gage or work chamber pressure transducer is indicated. Continue the experiment. • If the gage reading increases, a work chamber leak is indicated. A decision must be made whether or not to continue the experiment based on the amount of vacuum that can be maintained. 	Refer to P219A Remarks.

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TABLE J-V. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE - EXPERIMENT OPERATION (O) (Sheet 1 of 9)

Operation Step Number	Experiment/Crew Tasks	Possible Malfunction	Contingency Plan	Remarks (malfunctions, corrections, results)
O 1.2	INSTRUMENTATION BASE TEMP °C (S5) - range as indicated by INSTRUMENTATION TEMP gage M4.	O12A INSTRUMENTATION TEMP gage M4 reading is 0 °C or between 0 °C and 5 °C. (Corresponds to actual temperature of 0 to 50 °C.)	<p>O12A1 Place INSTRUMENTATION BASE + METER switch S8 in BASE + METER position and monitor INSTRUMENTATION TEMP gage M4</p> <ul style="list-style-type: none"> • If INSTRUMENTATION TEMP gage M4 reading increases, the temperature of the crystal growth package is extremely low. There is also a possibility that the crystal growth package sample ampoules have been damaged by freezing gallium arsenide solution. The package heater integrity check (Operation Step No. P 2 23) should be repeated (See Possible Malfunction P223B). If POWER CONTROL AM BUS 1 circuit breaker CB4 opens during the integrity check, terminate the experiment. If the circuit breaker does not open, recycle the following and continue the experiment: <ul style="list-style-type: none"> --COMPOSITE CASTING POWER switch S25 --CRYSTAL GROWTH POWER switch S10. • If INSTRUMENTATION TEMP gage M4 reading does not increase, refer to the following contingency plan: <ul style="list-style-type: none"> --O12A2 <p>O12A2 Recycle INSTRUMENTATION POWER SWITCH S2.</p>	<p>Possible failures that could cause a low temperature in the crystal growth package are COMPOSITE CASTING POWER switch S25 failing in the ON position, CRYSTAL GROWTH POWER switch S10 failing OFF, relay K2 failing open, 23-V regulator failure; and one or more crystal growth package heaters failing open.</p>

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TABLE J-V. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE - EXPERIMENT OPERATION (O) (Sheet 2 of 9)

Operation Step Number	Experiment/Crew Tasks	Possible Malfunction	Contingency Plan	Remarks (malfunctions, corrections, results)
O 1.2 (Continued).			<p>O12A3 Tap on gage face with finger.</p> <p>O12A4 Verify that POWER CONTROL AM BUS 1 circuit breaker CB4 and M512 circuit breaker are closed by switching FLOOD LT switch S19 to AM BUS 1</p> <ul style="list-style-type: none"> • If floodlight illuminates, refer to the following contingency plan --O12A5. • If floodlight does not illuminate, refer to the following contingency plan: --O12A6. <p>O12A5 Select positions 2, 4, or 6 on INSTRUMENTATION TEMP SOURCE switch S9, and monitor INSTRUMENTATION TEMP gage M4.</p> <ul style="list-style-type: none"> • If INSTRUMENTATION TEMP gage M4 reading increases, a malfunctioned thermocouple or failure of INSTRUMENTATION TEMP SOURCE switch S9 to make contact in one position is indicated. A partial loss of experiment data will occur, but the experiment can be continued. • If INSTRUMENTATION TEMP gage M4 does not operate, a malfunction is indicated in either the INSTRUMENTATION TEMP gage M4, the Power Supply Module, the 	<p>Settings 1, 3, and 5 on INSTRUMENTATION TEMP SOURCE switch S9 select crystal growth package cool-end thermocouples for measurement, and settings 2, 4, and 6 correspond to hot-end thermocouples. Therefore, rotating switch S9 from 1 to 6 should cause the INSTRUMENTATION TEMP gage M4 reading to vary alternately from low to high to low, etc.</p> <p>The failure can be isolated to the INSTRUMENTATION POWER switch S2 and the Power Supply Module by switching INSTRUMENTATION CSTR X3 switch S1 to</p>

TABLE J-V. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE - EXPERIMENT OPERATION (O) (Sheet 3 of 9)

Operation Step Number	Experiment/Crew Tasks	Possible Malfunction	Contingency Plan	Remarks (malfunctions, corrections, results)
O 1.2 (Continued)		O12B INSTRUMENTATION TEMP gage M4 reading is off scale high.	<p>Amplifier Module, the INSTRUMENTATION POWER switch S2 or the INSTRUMENTATION TEMP SOURCE switch S9. The experiment may be continued, but all temperature data will be lost. All positions of the INSTRUMENTATION TEMP SOURCE switch S9 should be tried to verify no temperature readings in any position.</p> <p>O12A6 Recycle POWER CONTROL AM BUS 1 circuit breaker CB4 and M512 circuit breaker and monitor the INSTRUMENTATION TEMP gage M4.</p> <ul style="list-style-type: none"> • If gage M4 operates, continue the experiment. • If gage M4 does not operate, a malfunction is indicated in either the POWER CONTROL AM BUS 1 circuit breaker CB4 or the M512 circuit breaker. The experiment will be terminated. <p>O12B1 Rotate INSTRUMENTATION BASE TEMP °C switch S5 through progressively higher settings and monitor the INSTRUMENTATION TEMP gage M4.</p> <ul style="list-style-type: none"> • If at some setting the gage indicator moves to a lower reading, this indicates that INSTRUMENTATION BASE + METER switch S8 has failed. 	CSTR X3. If INSTRUMENTATION PRESS gage M5 does not operate (nominal reading 8 psia) the Power Supply Module or switch S2 has failed.

TABLE J-V. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE - EXPERIMENT OPERATION (O) (Sheet 4 of 9)

Operation Step Number	Experiment/Crew Tasks	Possible Malfunction	Contingency Plan	Remarks (malfunctions, corrections, results)
O 1.2 (Continued)			<p>in the BASE + METER position Refer to the following contingency plan --O12B2</p> <ul style="list-style-type: none"> • If the gage indicator remains off scale high when the INSTRUMENTATION BASE TEMP °C switch S5 is placed in position 900, refer to the following contingency plan: --O12B3 <p>O12B2 Place INSTRUMENTATION BASE TEMP °C switch S5 in the next lower setting (indicator should move off scale high), recycle INSTRUMENTATION BASE + METER switch S8 and monitor INSTRUMENTATION TEMP gage M4.</p> <ul style="list-style-type: none"> • If gage indicator moves down scale, continue the experiment. • If gage indicator remains off scale high, continue the experiment. All temperature readings over 99 °C will be lost. <p>O12B3 Select position 1, 3, or 5 on INSTRUMENTATION TEMP SOURCE switch S9 and monitor INSTRUMENTATION TEMP gage M4.</p> <ul style="list-style-type: none"> • If INSTRUMENTATION TEMP gage M4 reading decreases, a malfunctioning thermocouple, or an exceptionally high 	<p>High package temperature could be caused by a malfunction of the 23-V regulator, or</p>

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TABLE J-V. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE - EXPERIMENT OPERATION (O) (Sheet 5 of 9)

Operation Step Number	Experiment/Crew Tasks	Possible Malfunction	Contingency Plan	Remarks (malfunctions, corrections, results)
O 1.2 (Concluded)			<p>package temperature ($> 990^{\circ}\text{C}$) is indicated. Continue with the experiment, recording those measurements that are within range of the display capabilities</p> <ul style="list-style-type: none"> If INSTRUMENTATION TEMP gage M4 reading does not decrease, a malfunction is indicated either in gage M4, in the Power Supply Module, or the Amplifier Module. The experiment may be continued, but all temperature data will be lost. 	failure of CRYSTAL GROWTH POWER switch S10 in the TEST position (23-V regulator bypassed).
O 1.3	INSTRUMENTATION BASE + METER (S8) - BASE + METER (mom).	O13A Reading on INSTRUMENTATION TEMP gage M4 does not vary.	<p>O13A1 Recycle INSTRUMENTATION BASE + METER switch S8</p> <p>O13A2 Tap on gage M4 face while holding INSTRUMENTATION BASE + METER switch S8 in BASE + METER position.</p> <p>O13A3 Select another position on INSTRUMENTATION BASE TEMP $^{\circ}\text{C}$ switch S5, then place INSTRUMENTATION BASE + METER switch S8 in BASE + METER</p> <ul style="list-style-type: none"> If the reading on gage M4 does not vary, a malfunction is indicated in either the INSTRUMENTATION TEMP gage M4, the INSTRUMENTATION BASE + METER switch S8, the Power Supply Module or the Amplifier Module. 	

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TABLE J-V. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE - EXPERIMENT OPERATION (O) (Sheet 6 of 9)

Operation Step Number	Experiment/Crew Tasks	Possible Malfunction	Contingency Plan	Remarks (malfunctions, corrections, results)
O 1.3 (Continued)			<p>The experiment may be continued but accurate (fine) temperature data will be lost (The coarse temperature monitoring capability will remain)</p> <ul style="list-style-type: none"> • If the reading on gage M4 does vary, log the original temperature reading and continue with the temperature recording 	<p>There are cases when the INSTRUMENTATION TEMP gage M4 reading will not vary from the METER X10 position to the BASE + METER position of INSTRUMENTATION BASE + METER switch S8. This occurs when the base temperature selected on INSTRUMENTATION BASE TEMP °C switch S5 equals nine times the INSTRUMENTATION TEMP gage M4 reading (i. e., when the actual temperature is 111 °C, 222 °C, 444 °C, 555 °C, 666 °C, 777 °C, or 888 °C).</p>
		O13B INSTRUMENTATION TEMP gage M4 goes off scale high.	<p>O13B1 Recycle INSTRUMENTATION BASE TEMP °C switch S5 to a higher setting, place INSTRUMENTATION BASE + METER switch S8 in the BASE + METER position, and monitor INSTRUMENTATION TEMP gage M4</p> <ul style="list-style-type: none"> • If the gage reading stabilizes at less than full scale, continue the temperature recording. • If the gage reading again goes off scale high when INSTRUMENTATION BASE + METER switch S8 is placed in BASE + METER, this is an 	<p>If the actual thermocouple temperature minus the setting on INSTRUMENTATION BASE TEMP °C switch S5 is greater than 99, the INSTRUMENTATION TEMP gage M4 indicator needle will go off scale high when INSTRUMENTATION BASE + METER switch S8 is placed in BASE + METER.</p>

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TABLE J-V. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE - EXPERIMENT OPERATION (O) (Sheet 7 of 9)

Operation Step Number	Experiment/Crew Tasks	Possible Malfunction	Contingency Plan	Remarks (malfunctions, corrections, results)
O 1.3 (Continued)		O13C INSTRUMENTATION TEMP gage M4 goes to 0	<p>indication that the INSTRUMENTATION BASE TEMP °C switch S5 has failed in a position out of range (low) of the actual thermocouple temperature, or that the Amplifier Module has malfunctioned. All positions of INSTRUMENTATION BASE TEMP °C switch S5 in combination with positions 1 through 6 of INSTRUMENTATION TEMP SOURCE switch S9 should be checked to verify the range of temperature measurement capability.</p> <p>The experiment may be continued, but accurate (fine) temperature data will be lost. (The coarse temperature monitoring capability will remain)</p> <p>O13C1 Recycle INSTRUMENTATION BASE TEMP °C switch S5 to a lower setting, place INSTRUMENTATION BASE + METER switch S8 in the BASE + METER position, and monitor INSTRUMENTATION TEMP gage M4</p> <ul style="list-style-type: none"> • If the gage reading stabilizes at greater than 0 °C, continue the temperature recording. • If the gage reading again goes to 0 °C when INSTRUMENTATION BASE + METER switch S8 is placed in BASE + METER, this is an indication that the 	<p>If the INSTRUMENTATION BASE TEMP °C switch S5 setting minus the actual thermocouple temperature is greater than 99, the INSTRUMENTATION TEMP gage M4 indicator needle will go to 0 °C when INSTRUMENTATION BASE + METER switch S8 is placed in BASE + METER.</p>

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TABLE J-V. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE - EXPERIMENT OPERATION (O) (Sheet 8 of 9)

Operation Step Number	Experiment/Crew Tasks	Possible Malfunction	Contingency Plan	Remarks (malfunctions, corrections, results)
O 1 3 (Concluded)			<p>INSTRUMENTATION BASE TEMP °C switch S5 has failed in a position out of range (high) of the actual thermocouple temperature, or that the Amplifier Module has malfunctioned. All positions of INSTRUMENTATION BASE TEMP °C switch S5 in combination with positions 1 through 6 of INSTRUMENTATION TEMP SOURCE switch S9 should be checked to verify the range of temperature measurement capability.</p> <p>The experiment may be continued, but accurate (fine) temperature data will be lost. (The coarse temperature monitoring capability will remain.)</p>	
O 3.3	Work chamber vent vlv - CLOSE.	O33A Work chamber vent valve fails OPEN.	<p>Refer to the following contingency plan:</p> <ul style="list-style-type: none"> • P220A1 <p>O33A1 Continue the experiment.</p>	The work chamber can be repressurized when the bulkhead vent valve is closed.
O 3.4	Bulkhead vent vlv - CLOSE.	O34A Bulkhead vent valve fails OPEN	<p>Refer to the following contingency plans</p> <ul style="list-style-type: none"> • P220A1 • O33A1. 	The work chamber can be repressurized because the work chamber vent valve is closed.

TABLE J-V. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE - EXPERIMENT OPERATION (O) (Sheet 9 of 9)

Operation Step Number	Experiment/Crew Tasks	Possible Malfunction	Contingency Plan	Remarks (malfunctions, corrections, results)
O 3.9	INSTRUMENTATION BASE TEMP °C (S5) - range as indicated by INSTRUMENTATION TEMP meter M4.	O39A INSTRUMENTATION TEMP meter M4 readings remain abnormally high (i.e., comparable to those taken on the last measurement series before switching the CRYSTAL GROWTH POWER switch S10 to OFF	O39A1 Open POWER CONTROL AM BUS 1 circuit breaker CB4, and wait 30 min before continuing with the temperature measurements.	An abnormally high temperature after switching crystal GROWTH POWER switch S10 to OFF indicates a failure of CRYSTAL GROWTH POWER switch S10 ON. Opening CB4 will remove power from the crystal growth package and will deactivate the M-512 facility control panel. The circuit breaker must be closed again for taking temperature measurements. This will reapply power to the crystal growth package, so temperature measurements should be taken as quickly as possible, then the circuit breaker should be reopened.

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TABLE J-VI. EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL GROWTH MALFUNCTION AND CONTINGENCY PLAN OUTLINE - EXPERIMENT TERMINATION (T)

Operation Step Number	Experiment/Crew Tasks	Possible Malfunction	Contingency Plan	Remarks (malfunctions, corrections, results)
	No contingencies are anticipated for the Termination portion of Experiment M-555.			

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SECTION IX.

**EXPERIMENT M-555, GALLIUM ARSENIDE SINGLE CRYSTAL
GROWTH MALFUNCTION ANALYSES**

Refer to Appendix E, Section IX for Experiment M-555 malfunction analyses.

SECTION X. CONCLUSIONS AND RECOMMENDATIONS

1. No Criticality I items were identified for Experiment M-555. Failures that prevent the readout of crystal growth package temperatures could present a burn hazard to the experiment operator if procedures are not followed carefully. Tests performed under the direction of the PI have developed proper cooldown times for the crystal growth package after experiment performance; therefore, inability to read package temperatures was not considered critical.
2. Some hardware items such as the heater blanket, experiment container, and experiment package could exceed touch temperature (105 °F). It is suggested that the experiment operator wear gloves while handling this equipment.
3. All probabilities of failure for experiment hardware were relatively low, and it is considered that the experiment has a good probability of success.
4. The experiment procedures as presented in the MDA Experiment Checklist and Log were used as a guide in preparing Section VII of this document. These procedures were modified in those cases where it was deemed necessary to make the procedures more efficient for the experiment operator, and necessary procedural steps were added where they had been omitted in the Checklist.

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